

The effect of an exercise and balance training intervention program on balance and mobility in community-dwelling older adults

Peter Accardo, BKin (Honours)

Submitted in partial fulfillment of the requirements for the degree of
Master of Science in Applied Health Sciences
(Kinesiology)

Faculty of Applied Health Sciences
Brock University
St. Catharines, ON

© December 2016

ABSTRACT

This thesis investigated the effect of a 12-week exercise and balance training intervention program on perceived and actual balance and mobility outcomes in healthy community-dwelling older adults. Forty-six older adults completed baseline testing including balance confidence and movement reinvestment questionnaires, and a series of balance and mobility tests. Those older adults who were randomly assigned to the intervention group participated in a 12-week program that included aerobic exercise, upper and lower body resistance training, flexibility training and balance training while those assigned to the control group were asked not to make any lifestyle changes during a 12-week control period. The same testing protocol was repeated upon completion of the 12-week intervention program or control period. The results indicated that the intervention group showed improved performance between baseline and 12-week testing sessions for two balance measures (e.g., faster Timed-Up and Go duration, fewer obstacle course errors) while there was no change observed in these measures in the control group. There was also a trend observed for higher balance confidence and less movement self-consciousness reinvestment at the 12-week compared to baseline testing session for the intervention group while no change in these measures was observed in the control group. The findings suggest that participating in 12 weeks of an exercise and balance training intervention can effect change in select perceived and actual balance outcome measures in healthy community-dwelling older adults.

Keywords: Balance, mobility, obstacle course, intervention program, older adults

Acknowledgements

First and foremost, I would like to thank my supervisor Dr. Allan Adkin for his continuous support and guidance over the course of my graduate degree. When life throws you a curveball and knocks you off balance, you have always provided me with the lessons and modifications needed to take the next step. I am grateful for everything you have done throughout this process as it has shaped me into the person who I am today.

I would also like to acknowledge the members of my advisory committee, Dr. Kimberley Gammage and Dr. Craig Tokuno, for their precious time and advice in providing me with the best possible thesis. Kim, I have to thank you particularly for introducing me to BASICS, where I developed my passion in helping older adults. As one door closes, another one opens - I know the next chapter of my life will be surrounded by the memories and passion established from what you introduced me to. I would like to thank the participants involved in this study, other tests and the intervention staff for their constant availability and dedication. This thesis would not have been possible without your involvement, for which I am grateful.

I also need to thank my past/present lab mates, and graduate student friends. The conversations we had and laughs we shared will always be remembered. Laughter is the best medicine and it made this long journey entertaining.

I would also like to extend my sincerest gratitude to my mother and father. You have always encouraged me to further my education and have been supportive throughout this entire process. I know you are proud parents of what I have accomplished. To everyone listed above, thank you for making this experience a memorable one. Surgite!

TABLE OF CONTENTS

CHAPTER ONE: LITERATURE REVIEW	1
1.1 Falls in older adults.....	1
1.2 Age-related changes in balance control	1
1.3 Balance control system	2
1.3.1 Task constraints.....	3
1.3.2 Environmental context	5
1.4 Balance confidence and movement reinvestment.....	7
1.5 Exercise and balance training interventions	9
1.6 Using an obstacle course to assess balance performance	13
CHAPTER TWO: RATIONALE, PURPOSE, AND HYPOTHESES	18
2.1 Rationale	18
2.2 Purpose	19
2.3 Hypotheses.....	20
CHAPTER THREE: METHODOLOGY	21
3.1 Participants	21
3.1.1 Sample size estimation.....	21
3.2 Assignment to intervention or control group.....	22
3.3 Experimental protocol	23
3.3.1 Demographic and anthropometric measures	23
3.3.2 Balance confidence and movement reinvestment questionnaires.....	24
3.3.3 Balance and mobility tests	25
3.4 Intervention program	38

3.4.1	Clearance for participation in physical activity	38
3.4.2	Summary of the intervention program	38
3.4.3	Orientation to the intervention program.....	39
3.4.4	Overview of the intervention program.....	39
3.4.4.1	Aerobic exercise.....	40
3.4.4.2	Resistance training	40
3.4.4.3	Flexibility	41
3.4.4.4	Balance training	41
3.5	Statistical analysis.....	42
3.5.1	Intervention effects	43
CHAPTER FOUR: RESULTS		44
4.1	Data screening and statistical assumptions.....	44
4.1.1	Outliers.....	44
4.1.2	Normality	45
4.1.3	Assumptions of repeated-measures analysis of variance	48
4.1.3.1	Homogeneity of variance.....	48
4.2	Descriptive statistics	51
4.3	Power and effect sizes	52
4.4	Intervention effects	53
4.4.1	Perceived balance outcome measures	54
4.4.1.1	Balance confidence	54
4.4.1.2	Movement reinvestment (CMP, MSC)	55
4.4.2	Actual balance outcome measures	56

4.4.2.1	One leg stance	56
4.4.2.2	Normal walk.....	57
4.4.2.3	Timed-up-and-go (TUG).....	57
4.4.2.4	Functional reach.....	58
4.4.2.5	Obstacle course	58
CHAPTER 5: DISCUSSION	61
5.1	Characteristics of the sample at baseline	62
5.2	Effect of the intervention program on perceived balance outcome measures	64
5.2.1	Balance confidence	64
5.2.2	Movement reinvestment (CMP, MSC)	67
5.3	Effect of the intervention program on actual balance outcome measures	69
5.3.1	Timed-up-and-go (TUG) performance	69
5.3.2	Obstacle course performance	70
5.3.3	One leg stance and functional reach	73
5.4	Strengths and limitations	74
5.4.1	Sample	74
5.4.2	Balance testing.....	75
5.4.3	Intervention program	76
5.5	Future directions	78
5.6	Conclusions.....	79
References	80
Appendix A – Ethical Clearance	87
Appendix B – Informed Consent	89

Appendix C – Demographic Questionnaire	93
Appendix D – The Activities-specific Balance Confidence Scale	95
Appendix E – Trait Version of the Movement Specific Reinvestment Scale.....	97
Appendix F – The Physical Activity Readiness Questionnaire	99
Appendix G – BASICS Exercise Log Sheet.....	101

LIST OF TABLES

Table 1. Balance and mobility tests completed during each testing session and associated outcome measures.	26
Table 2. Operational definitions for errors committed on each subcomponent of the obstacle course.	35
Table 3. Skewness and kurtosis statistics for perceived and actual balance and mobility outcome measures by group and time.....	47
Table 4. Bivariate correlations for perceived and actual balance and mobility outcome measures at baseline for the intervention (A) and control (B) group and at 12-weeks for the intervention (C) and control (D) groups.....	49
Table 5. Descriptive statistics for demographic and anthropometric variables by group and time.....	52
Table 6. Post hoc power analyses and effect sizes for all perceived and actual balance and mobility outcome measures	53
Table 7. Mean (standard deviation) values for perceived and actual balance and mobility outcome measures at baseline and 12-week testing sessions for the intervention and control groups	54

LIST OF FIGURES

Figure 1: Schematic view of the OC and the five distinct subcomponents	31
Figure 2: Camera view of the OC and the five distinct subcomponents.....	32
Figure 3: Mean ABC scores for baseline and 12-week testing sessions for the intervention and control groups.....	55
Figure 4: Mean MSC scores for baseline and 12-week testing sessions for the intervention and control groups	56
Figure 5: Mean TUG duration for baseline and 12-week testing sessions for the intervention and control groups	58
Figure 6: Mean number of obstacle course errors for baseline and 12-week testing sessions for the intervention and control groups.....	60

CHAPTER ONE: LITERATURE REVIEW

1.1 Falls in older adults

Falls and their consequences in older adults are a major health care issue. Approximately 30% of individuals 65 years of age or older fall each year (Rubenstein, 2006; Speechley, 2011). A fall may result in physical injury (e.g., fracture) or psychological consequences (e.g., fear of falling) evoking behavioural changes including the restriction of physical and social activities resulting in reduced muscle strength, balance, and mobility (Legters, 2002; Tinetti & Williams, 1998). These post fall complications can ultimately lead to a loss of independence and reduced quality of life (Legters, 2002).

In 2011, an estimated 5 million Canadians or 15% of the population were 65 years of age or older (Statistics Canada, 2014). It is predicted that by the year 2036, 30% of the Canadian population will be represented by individuals of this age (Statistics Canada, 2014). Thus, as this is the fastest-growing age group, it is important to identify strategies to limit falls and their consequences in older adults.

1.2 Age-related changes in balance control

Balance problems are common in older adults (Lord, Sherrington, Menz, & Close, 2007). Poor balance has been identified as an important risk factor for falls in older adults (Rubenstein, 2006; Speechley, 2011; Tinetti & Kumar, 2010). In addition to poor balance, impaired gait, impaired cognition, psychoactive and multiple drug use, depression, dizziness, arthritis, diabetes mellitus, and pain have consistently been identified as risk factors for falls (Tinetti & Kumar, 2010). Deficits in the visual, proprioceptive, and vestibular sensory systems, coupled with reduced muscle strength

and slowed reaction time contribute to age-related changes in balance and increase the risk of falls in older adults (Lord et al., 2007; Sturnieks, George, & Lord, 2008). Research has revealed that normal ageing is associated with decreased performance observed across a variety of tasks including for example standing, walking, responding to external perturbations, and transfers (Lord et al., 2007; Sturnieks et al., 2008). It has also been shown that ageing is associated with modifications to strategies for stepping over or avoiding obstacles, walking on stairs, and responding to trips and slips (Lord et al., 2007). Further, psychological factors (e.g., fear of falling) and cognitive factors (e.g., attention) may further compound age-related changes in the balance control system. For example, balance tasks demand more attention with increasing age where the concurrent performance of cognitive tasks interferes with the primary task of maintaining balance (Lord et al., 2007).

1.3 Balance control system

Balance is important for the successful completion of activities of daily living (ADLs). Balance control is now considered a complex motor skill achieved through the dynamic interaction of multiple sensorimotor systems, including the visual, vestibular and somatosensory systems, to generate appropriate motor responses in order to complete balance tasks and ADLs (Horak, 2006; Maki & McIlroy, 1996).

Horak (2006) describes balance control as a multi-dimensional system composed of six subcomponents. The interaction of biomechanical constraints (e.g., manipulating size and quality of the base of support), movement strategies (e.g., ankle, hip, step or grasp), sensory strategies (e.g., manipulating sensory information from visual, somatosensory, and vestibular systems), orientation in space (e.g., adapting to standing

on an unstable or inclined surface), control of dynamics (e.g., maintaining stability while walking), and cognitive processing (e.g., dual tasking) all contribute to overall balance control (Horak, 2006). The assumption of having a single balance system leads to the belief that prescribing a single balance test can be used to effectively measure the performance of the balance control system. However, based on the systems approach this is not the case; no one balance test would be able to identify the performance of the balance control system (Horak, 2006). Importantly, among a group of older adults, individuals may have a unique combination of constraints and available resources that differentially affect balance control. Therefore, the systems approach for assessing balance control includes the multiple systems that are involved when performing ADLs. Due to individual differences, it is noted that age-related changes in these balance system subcomponents will vary across older adults (Horak, 2006). With aging, there may be an increased likelihood of having difficulties for one or more of these balance system subcomponents. Thus, it is important to examine balance control across as many balance subcomponents as possible. Further, the interaction between individual constraints (e.g., age-related changes in sensory, motor, and cognitive systems), the task to be performed (e.g., instructions, changes in base of support or altering sensory information) and the environmental context (e.g., predictable or unpredictable) is important to consider when understanding balance control in older adults (Huxham, Goldie, & Patla, 2001).

1.3.1 Task constraints

The difficulty of the balance task is important to consider when examining balance control in older adults and altering the constraints of the balance task can provide important insight into how the balance control system is performing. For example,

normal preferred pace walking is less challenging to balance control than when walking on a narrow surface or when given instructions to walk very slowly or very fast. The restricted base of support or the given instruction will constrain walking performance and challenge the balance control system to meet the demands being placed on it (Huxham et al., 2001). As described earlier with respect to the subcomponents of balance control, there are certain biomechanical and cognitive processing characteristics involved with balance control that will change when performing more difficult balance tasks or ADLs (Horak, 2006).

The balance task being performed determines the magnitude, direction, and accelerations of the forces that will be placed on the body and that must be accounted for in order not to lose balance (Huxham et al., 2001). For example, the biomechanical challenges in quiet standing and walking are very different due to what needs to be done to control the center of mass. This is due to the fact that the center of mass lies outside of the base of support for 80% of the gait cycle during walking and must be controlled with each step and inside it and maintained within it during quiet standing (Winter, 1995). The movement of the center of mass during quiet standing is minimal compared to walking or turning tasks (Huxham et al., 2001). After establishing whether the base of support remains stationary or moves during the task, tasks can be categorized in accordance with the internal (e.g., waving an arm when walking) or external (e.g., nudged when walking through a crowd) challenges placed on the body. For the purposes of this thesis, assessment tools focused on self-generated or internal perturbations (e.g., functional reach test, timed-up and go (TUG) test, navigating through an obstacle course).

1.3.2 Environmental context

In addition to the constraints associated with the task, the environment in which the task takes place will influence the way in which it is able to be performed (Huxham et al., 2001). For example, walking across an icy surface may result in shorter, more cautious steps compared to walking through an uncrowded mall. Walking through a busy market will demand different visual search strategies compared to walking alone along an empty street (Huxham et al., 2001).

The environmental context of a task can alter its biomechanical characteristics in two important ways (Patla, 1997). First, walking patterns will need to be modified when walking on different support surfaces such as compliant or inclined surfaces (Huxham et al., 2001). Second, avoidance strategies are implemented when external demands from the environment are placed on balance control. Patla (1997) suggested that balance is maintained through two main types of avoidance strategies. The first strategy includes proactive and predictive control mechanisms which are used to remove, reduce or counteract any perturbations that will be placed on the body. The second strategy includes automatic reactive control mechanisms that are used if the proactive or predictive control mechanisms are unable to maintain balance or if an unexpected external disturbance is experienced.

Proactive balance control relies on the visual system; information about changes in the environment is received through vision and interpreted based on experience to select the most appropriate strategy to maintain balance (Patla, 1997). For example, we can choose to step around or to step over an obstacle, to reduce our walking velocity when navigating across a challenging surface such as ice or try to avoid it altogether by

selecting an alternate route (Huxham et al., 2001). Predictive balance control considers the forces that will be acting on or within the body. Predictive control is largely achieved through anticipatory postural adjustments (Patla, 1995). These patterns of muscle activity are initiated before most voluntary movements (Huxham et al., 2001) and are based on previous experience to determine the magnitude and direction of the disturbance to the center of mass that will be produced by the voluntary movement (Patla, 1995). These adjustments are also important for starting voluntary movement. For example, when starting to walk, anticipatory postural adjustments initiate center of mass movement towards the new base of support provided by the stance leg before the swing leg is lifted and moved forward (Huxham et al., 2001). Using these strategies, the balance control system acts to proactively monitor the external environment and predict the effects of forces generated by the voluntary movement on the body to maintain balance when performing ADLs (Huxham et al., 2001).

The complexity of the environment and whether the environment changes while performing the task will influence the amount of information processing or attentional resources required. Walking through an uncrowded room will require fewer resources than when walking through a similar room filled with chairs or tables (Huxham et al., 2001). Additionally, most environments that individuals encounter everyday are not fully predictable. If people were walking around the room at different speeds and in directions, the resources required to avoid colliding with the stationary and moving objects would increase; this demand for resources may potentially compromise balance control in individuals with limited resources such as older adults (Huxham et al., 2001).

From this discussion, balance control depends on the interaction between the constraints placed on the individual (e.g., age-related sensory, motor, cognitive and emotional constraints), the demands of the task, and the context of the environment (e.g., predictable or unpredictable). It is important to consider this dynamic interaction when training or assessing balance in older adults (Huxham et al., 2001).

1.4 Balance confidence and movement reinvestment

Balance confidence is considered a psychological factor that can influence balance control (Schepens, Sen, Painter, & Murphy, 2012). It is defined as an individual's confidence level in maintaining balance while performing ADLs and is assessed through a questionnaire (Powell & Myers, 1995). It has been shown that low balance confidence is associated with activity restriction, which itself can lead to deconditioning and influence an older adults' ability to perform tasks (Hadjistavropoulos et al., 2012). Importantly, lower levels of balance confidence are associated with balance problems (Cho, Scarpace, & Alexander, 2004; Schepens et al. 2012) and falls (Lajoie & Gallagher, 2004) in older adults.

The term reinvestment is used to describe the amount of conscious control directed to the performance of a motor skill and it can be considered a cognitive factor that can influence balance performance (Masters & Maxwell, 2008). Movement reinvestment is a personality trait that reflects an individuals' propensity to direct attention to the control and/or perception of their movement. The Movement Specific Reinvestment Scale (MSRS) was developed to measure the tendency for an individual to consciously control their movements (Masters, Eves, & Maxwell, 2005; Masters & Maxwell, 2008). The MSRS is composed of two subscales: conscious motor processing

(CMP) and movement self-consciousness (MSC). CMP reflects an individual's tendency to consciously control the processes associated with their movement or the mechanics of their movement, while MSC reflects an individual's concern over their movement style (Masters & Maxwell, 2008). It is theorized that individuals higher in these traits are more likely to attempt to consciously attend to their movement under challenging task conditions (Masters & Maxwell, 2008). This change in cognitive strategy is thought to be inefficient, particularly for well-learned movements; conscious intervention may disrupt the automatic organization of the movement leading to poorer performance. Support for this claim has been provided by research showing that individuals classified as high movement reinvestors demonstrate poorer performance across a variety of motor skills including balance (Masters & Maxwell, 2008). The MSRS has been used to determine differences in trait movement reinvestment in older adults, showing that elderly fallers reinvest more in their movements than elderly non-fallers, and that the CMP subscale was a better discriminator between fallers and non-fallers compared to the MSC subscale (Wong, Masters, Maxwell, & Abernethy, 2008)

Therefore, psychological and cognitive factors in combination with age-related physiological changes in older adults must be considered when trying to understand balance control in this population. Further, possible ways to modify these factors to improve balance control need to be found. The implementation of an exercise and balance training intervention may be one option to address these constraints with the ultimate goal of improving balance performance and reducing fall risk (Howe, Rochester, Neil, Skelton, & Ballinger, 2011).

1.5 Exercise and balance training interventions

It is well recognized that exercise and/or balance training interventions can improve certain aspects of balance and mobility in healthy older individuals (Howe et al., 2011). For example, improvements in balance confidence have been observed following an exercise and balance training intervention program (Clemson et al., 2004; Liu-Ambrose, Khan, Eng, Lord, & McKay, 2004; McKinley et al., 2008; Schilling et al., 2009; Ullmann, Williams, Hussey, Durstine, & McClenaghan, 2010; Weerdesteyn et al., 2006). Interventions that combine different types of training components (e.g., resistance training, and balance training) while challenging individuals with tasks experienced in daily life provide the best outcome in improving balance confidence (Büla, Monod, Hoskovec, & Rochat, 2010; Rand, Miller, Yiu, & Eng, 2011). Performance on clinical balance assessment tests such as the TUG have also been shown to improve following an intervention program (Jehu, Paquet, & Lajoie, 2016; Liu-Ambrose et al., 2008; Schilling et al., 2009). A variety of different tasks (e.g., static and dynamic balance tasks, postural recovery tasks, etc.) have also shown improvements after participation in an exercise and balance training program while other tasks have not, emphasizing the possible importance of selection of the balance task in determining the efficacy of the intervention (Howe et al. 2011).

However, due to a number of limitations associated with this literature, a pattern or consistent strategy outlining how exercise and balance training can impact balance and mobility remains unclear. A variety of interventions using different types of exercise and/or training methods have been used by researchers to determine if these interventions can minimize age-related changes to the balance control system. The nature of the

intervention and its training components have varied ranging from gait, balance, and mobility training, to strengthening exercises (e.g., resistance training, power training), to full body movements (e.g., Tai Chi, dance, yoga), to general physical activity (e.g., walking, cycling), to computerized balance training using sensory feedback, to whole body vibration platforms, and to exergaming (e.g., Wii, Kinect; Howe et al., 2011). In addition to the different types of interventions employed, the training modalities and characteristics defining the intervention program have also varied. A recent review has highlighted this problem and suggested that a challenging balance training program should consist of a training period of at least 12 weeks in duration that involves three sessions per week with approximately 30-45 minutes devoted to a single training session in order to show benefits in balance control as assessed through a wide variety of balance outcomes (e.g., from static balance tests to perturbed balance tests to walking tests; Lesinski, Hortobágyi, Muehlbauer, Gollhofer, & Granacher, 2015). The training must also be performed at a moderate to high intensity level in order to show benefits to balance control in healthy older adults aged 65 years or age or older (Lesinski et al., 2015).

Research has also highlighted the importance of interventions that combine different types of exercise and balance training components; these types of programs provide the best outcomes in effecting changes in balance control in older adults (Howe et al., 2011). For example, Lord and colleagues (1995) examined the effects of a 12-month exercise and balance training program on a number of different outcomes including strength, balance, and falls in 197 community-dwelling older women. Those randomly assigned to the exercise group (n=100) underwent a 12-month exercise

program that involved aerobic, strengthening, balance, flexibility, and hand/foot/eye coordination exercises. No information was provided for the procedural instructions for the control group ($n=97$). Therefore, it is assumed that participants in the control group assumed usual activity. The exercise program involved attending two one hour sessions each week in a supervised group setting. Assessments were made prior to, midway through, and at the end of the exercise program. The exercise group showed significant improvements in lower limb muscle strength, reaction time, and postural control (e.g., decrease in sway amplitude for standing balance tasks) measures. In contrast, no significant improvements were observed for all outcome measures in the control group. The authors concluded that exercise could produce long-term benefits with regard to improving function in older women.

Weerdesteyn and colleagues (2006) examined the effects of the Nijmegen Falls Prevention Program in community-dwelling older adults with a history of falls. A total of 107 older adults were used in this study (e.g., exercise group, $n=79$; control group, $n=28$). Older adults randomly assigned to the exercise group completed a 5-week exercise program while older adults randomly assigned to the control group did not receive any specific treatment. The exercise program involved two 1.5 hour sessions each week. The first session focused on training on an obstacle course in order to simulate ADLs. Tasks involved in the obstacle course included walking over various obstacles, reaching from a stool, standing up from a low chair without the use of arms, and making a transfer from stance to a kneeling position. To simulate the complexity of ADLs, the tasks were performed at the same time as other motor and cognitive tasks, and under different visual conditions. The second session focused on walking tasks (e.g., walking in

crowded areas at varying speeds and through different directions) and practicing forward/backward and sideways fall techniques. The researchers found no difference between the exercise and control groups in standing balance control outcomes or in the ability to weight shift. However, improvements in the exercise compared to control group were observed on a treadmill obstacle avoidance test (e.g., higher success rates, faster response times) and level of balance confidence (e.g., more confident; Weerdesteyn et al., 2006). These two studies suggest that an intervention program that addresses multiple components of the balance system may provide greater benefit compared to programs that focus on a single component.

Due to the selection of varied balance tasks and the multiple outcomes measures used to capture changes in the balance control system in response to the intervention, it is also difficult to draw accurate conclusions concerning the effectiveness of intervention programs (Howe et al., 2011). The large number of outcome measures used in the literature ranges from quantitative posturography (e.g., force plate, accelerometers, gait kinematics) to more simple measures obtained from functional balance tasks (e.g., TUG duration) to subjective evaluation measures (e.g., Dynamic Gait Index, Berg Balance Scale; Howe et al., 2011). Thus, it appears to be important to examine multiple outcome measures that provide or capture the many subcomponents of the balance control system as outlined by Horak (2006). These outcomes should range from performance on static balance tasks to performance on functional mobility tasks. However, due to the influence of task and environmental constraints, the use of assessment tools to provide more real life challenges to functional mobility should be considered. An obstacle course was created as a tool for the assessment of functional balance and mobility in older adults

(Means, 1996). The focus of this thesis is to examine the effects of an exercise and balance training program on balance control and mobility using an obstacle course as a primary outcome measure in community-dwelling older adults. Training on an obstacle course during the course of the intervention is included.

1.6 Using an obstacle course to assess balance performance

Mobility is defined as the ability to move independently and safely from one location to another (Patla, 2001) and is critically important for completing ADLs. A study outlining environmental demands on gait in older adults showed that environments routinely encountered at home and within the community are complex (Shumway-Cook et al., 2002). Thus, as mobility is most often carried out in these complex environments, balance and mobility should be assessed in a similar manner if possible.

Although there is a lack of tools to assess mobility across a number of different tasks, an obstacle course has been used as a tool for the assessment of balance and mobility in older adults (Means, 1996). The functional obstacle course (FOC) was developed to evaluate balance and mobility impairments in older adults when performing simulated real-life ADLs. The FOC assesses performance on a series of twelve tasks or simulations of common tasks that may be encountered in and around the home. The FOC includes different stations with various types of floor surfaces, two ramps, two sets of stairs, and four discrete functional movement tasks (e.g., opening a door, rising from a chair, walking around, and stepping over obstacles; Means, 1996). Performance on the FOC was video-recorded and duration and quality scores were obtained. Quality scores were assigned for the presence or absence of compensatory strategies or apparent difficulty with balance and mobility during the performance of each of the tasks within

each station of the FOC. Performance was rated for each task on an ordinal scale, ranging from “unable to complete the task without assistance” [0] to “no observed difficulty or apparent unsteadiness while performing the task” [3]. An overall quality score was determined by summing the 12 individual quality scores (maximum score = 36). Each obstacle course performance generated 1 overall and 12 individual duration scores, and 1 overall and 12 individual quality scores. The results showed that mean overall obstacle course duration was 274.6s (SD=131.2s) for all participants combined, with fallers being slower than non-fallers. The mean overall obstacle course quality score was 30.4 (SD=6.47) for all participants combined, with fallers having a lower score compared to non-fallers.

This original FOC was developed to assess older adults with and without balance and mobility impairments within a hospital-based setting (Means, 1996). A new modified version of the FOC was developed for use in a community-based setting (Means & O’Sullivan, 2000). The modifications included placing stations (e.g., artificial turf, carpet, pine bark, sand, and up and down ramps) next to a wall instead of in their original location between parallel bars. The modified FOC was set up with the same sequence of obstacles and the same inter-obstacle distances as the original FOC (Means, 1996). Due to the possibility of altered performance scores with the modifications, 36 older adults were tested on the modified and original versions of the FOC (Means & O’Sullivan, 2000). The results showed no difference in quality scores between the two versions as well as no interaction effect between faller status and obstacle course version.

To establish concurrent validity (e.g., how well a test correlates with a previously validated measure) of the FOC, Means and colleagues (1998) examined the relationship

between performance scores (e.g., duration and quality) on the FOC and scores on the performance oriented mobility assessment (POMA; lower scores on this assessment tool indicate poorer balance and mobility) and postural sway measures. FOC duration was negatively correlated with both the balance and gait subscales of the POMA, and the POMA total score. FOC quality scores were positively correlated with POMA balance and gait subscales, and the POMA total score. FOC duration was positively correlated with sway area with eyes open and closed but not with visual feedback. FOC quality scores were negatively correlated with sway area with eyes open and closed but not with visual feedback. It was also shown that POMA gait and balance measures accounted for most of the variance found in the FOC duration and quality scores (Means, Rodell, O'Sullivan, & Winger, 1998).

Knowing the benefits of an exercise and balance training intervention in reducing the occurrence of potential future falls in older adults, research has assessed the short-term effect of an exercise-based rehabilitation intervention on balance and mobility using obstacle course scores as primary outcome measures (Means, Rodell, O'Sullivan, 2005; Rubenstein et al., 1997).

Rubenstein and colleagues (1997) used an obstacle course that mimicked similar challenges to balance control than that of the FOC (Means et al., 2005). The obstacle course consisted of six different tasks: tandem walking, balance ladder with foam, ramp and stairs, picking up an object, avoiding hanging obstacles, and stepping over a block. Men 70 years of age or older completed a 3-month exercise intervention targeted to older adults at risk for falling (e.g., weakness in one or more lower extremity muscle groups, a gait or balance impairment assessed through the POMA, and a recent history of falling).

The intervention consisted of three 90-minute supervised group exercise sessions per week that focused on lower extremity strengthening using ankle weights, balance training (e.g., balance board, beam, ball toss), and gait training (e.g., walking indoors and on a treadmill). The obstacle course used has been shown to be a reliable and valid assessment tool for balance and functional mobility in fall-prone older adults (Means, Rodell, & O'Sullivan, 1996). Obstacle course scores (e.g., quality and duration) showed significant improvement among the most impaired older men, but not among higher functioning older men following the exercise intervention.

Means and colleagues (2005) targeted low-risk, community-dwelling older adults. They underwent 6-weeks of active stretching, balance, endurance, coordination, and strengthening exercises at moderate intensity that was progressive. Participants attended training sessions three times per week for 6-weeks with each session lasting approximately 90 minutes. Participants in the control group attended a series of seminars on various, non-health related topics of general interest to older adults (e.g., tax preparation, gardening, fishing, etc.,) The amount of time spent in the seminars was equal to the amount of time that other participants spent in the exercise intervention sessions. FOC performance scores (e.g., duration and quality) were evaluated at baseline, 6-weeks, and 6-months post-intervention

The results indicated a significant interaction effect for both FOC duration and quality. From baseline through 6-months follow up, participants in the exercise intervention group significantly outperformed those participants in the control group. At baseline, the exercise intervention group averaged 244s to complete the FOC. FOC duration scores improved 7.4% (226s) at 6-weeks and 8.2% (224s) at follow-up for the

exercise intervention group. Controls averaged 235s to complete the FOC at baseline and improved 4.0% (226s) at 6-weeks and 3.4% (227s) at follow-up. Therefore, the exercise intervention group showed improvement in FOC duration scores after the program and maintained these changes at the follow-up testing session. For FOC performance quality scores, the exercise intervention group improved 2.1% at 6-weeks and 1.5% at follow-up compared with 0.3% improvement for the control group for each time period ($p=0.001$). The findings of Means and colleagues (2005) as stated are statistically significant but clinically modest in terms of FOC performance. Although balance and coordination exercises were implemented in the intervention program, the tasks chosen may not have sufficiently challenged the participants considering that the sample was functional, independent low-risk community-dwelling older adults. Also, balance control is achieved through the dynamic interaction of multiple sensorimotor systems (e.g., visual, somatosensory, and vestibular). Manipulating any of these sensorimotor systems (e.g., altering the support surface) will increase the difficulty of the task and stress reliance on feedback from the individual systems needed to maintain balance. All of the balance tasks performed in the exercise intervention were performed on a firm support surface, eliminating any contributions of somatosensory influences on balance control. Therefore, the balance component of an intervention should include a progressive element and incorporate the multiple subcomponents that influence balance control outlined by Horak (2006).

CHAPTER TWO: RATIONALE, PURPOSE, AND HYPOTHESES

2.1 *Rationale*

As senior citizens, individuals 65 years of age or older make up the fastest-growing age group in Canada. Falls and their consequences are a major health care issue for this group (Statistics Canada, 2014). It is estimated that 1/3 of older adults 65 years of age and older fall each year (Rubenstein, 2006; Speechley, 2011). A fall may produce primary (e.g., falls-related injury) and/or secondary (e.g., activity restriction, socially withdrawal, reductions in strength, balance, and mobility) complications that ultimately lead to a reduced quality of life, loss of independence and hospitalization (Legters, 2002; Reelick, Van Ersel, Kessels, & Olde Rikkert, 2009). Therefore, it is pivotal to examine strategies for falls prevention.

Balance control is a multi-dimensional system composed of many subcomponents that involves the dynamic interaction of multiple sensorimotor systems (Horak, 2006). Although balance control is an integral component of all daily activities and an important risk factor for falls, its complex nature makes it difficult to adequately assess. Balance is affected by task and individual constraints and the environmental context altering biomechanical aspects and cognitive processing involved with balance control (Huxham et al., 2001). Also, understanding age-related changes in the sensorimotor and physiological systems crucial to balance control is important to prevent falls in the elderly (Lord et al., 2007; Sturnieks et al., 2008).

In order to improve balance and reduce risk factors for falls and fall-related injuries among seniors, exercise and balance training programs have been examined (Howe et al., 2011). The efficacy of a number of different types of programs has been

explored with methodological inconsistencies and varied results within the literature (Howe et al., 2011). Limitations with these studies are related to the training program used, with many programs focusing on the effects of one type of training program (e.g., strength, balance; Howe et al., 2011). As well, limitations may arise as to the type of balance tests that are assessed as many focus on a single type of balance test (such as standing or walking or performance on a standard balance assessment tool such as the TUG test; Howe et al., 2011).

Due to scarce availability of adequately assessing functional mobility, the obstacle course was created as a tool for the assessment of functional balance and mobility in older adults (Means, 1996). The obstacle course incorporates common tasks designed to challenge different strategies used in balance control and mobility encountered in and around the home environment (Means & O'Sullivan, 2000). Previously used in an exercise and balance intervention (Means et al., 2005), small but significant improvements in performance after the intervention were observed using the obstacle course as a primary outcome measure. However, the nature of the balance exercises incorporated in the intervention failed to address the multiple subcomponents and strategies involved in balance control outlined by Horak (2006) and may have contributed to the small improvements observed.

2.2 *Purpose*

The purpose of this thesis was to determine the efficacy of a 12-week exercise and balance training intervention program on perceived and actual balance outcomes in healthy community-dwelling older adults. The intervention included aerobic exercise, upper and lower body resistance training, flexibility training and balance training. The

balance training primarily used an obstacle course set-up that could be modified to provide multiple task and environmental challenges to the balance control system. The impact of the exercise and balance training intervention program was assessed using a variety of standard as well as novel perceived and actual balance outcome measures.

2.3 *Hypotheses*

It was hypothesized that a significant interaction effect between participant group (e.g., intervention, control) and time (e.g., baseline, 12-week) would be observed for all perceived and actual balance outcome measures.

First, it was expected that balance confidence would increase from baseline to the 12-week testing session in the intervention group while no change in balance confidence would be seen in the control group across the two testing sessions. Second, it was hypothesized that movement reinvestment, including conscious motor processing and movement self-consciousness reinvestment, would decrease from baseline to the 12 week testing session in the intervention group while no change in either of these measures would be observed in the control group across the two testing sessions. Third, it was expected that performance on all of the actual balance tests would improve from baseline to the 12 week testing session (e.g., longer one leg stance durations, shorter normal walk durations, shorter TUG durations, increased functional reach distances, shorter obstacle course durations and fewer obstacle course errors) in the intervention group while no change in performance on these tests would be seen in the control group across the two testing sessions.

CHAPTER THREE: METHODOLOGY

3.1 *Participants*

The present thesis examined a subset of data from healthy older adults involved in an ongoing study called Balance and Strength in Community Seniors (BASICS).

Participants had to be 65 years of age or older. Consistent with previous research examining exercise and balance training intervention programs for improving balance in older adults (Howe et al., 2011), exclusion criteria were set as any self-reported neurological (e.g., Parkinson's disease, multiple sclerosis, stroke), musculoskeletal (e.g., osteoporosis, joint replacement within the past year) or sensory deficit (e.g., diabetes) or anyone undergoing active treatment for cancer. Participants had to be able to walk independently without the use of an assistive device and without physical assistance, live independently within the community, and have access to transportation to travel to Brock University and the location of the intervention program (Brock Research and Innovation Centre; BRIC).

3.1.1 *Sample size estimation*

Pre-experimental sample size estimation and power analysis were determined in accordance with Cohen's (1988) four criteria to establish *a priori* determination of: 1) the level of significance (α), 2) the appropriate power value (β), 3) the mean (\bar{x}) and true score (σ^2) variance of the sample criterion measure, and 4) the effect size (η^2). To satisfy the 4-to-1 risk ratio (Type I (β) to Type II (α) error suggested by Cohen (1988), the level of significance and appropriate power value was set (e.g., $\alpha=0.05$ and $\beta=0.20$) which would allow for a power ($1 - \beta$) of 0.80. Based on the work of Jehu and colleagues (2016) looking at TUG durations, with reported descriptive means, standard deviations and true

variance scores, an effect size (η_p^2) of 0.76 was reported. To maintain the same effect size and achieve a significant effect for TUG duration, a sample size of 10 participants per group would have been needed. Looking at balance confidence (Schilling et al., 2009), a standardized effect size was calculated to be 0.72). To achieve a significant effect for balance confidence, a sample size of 7 participants per group would have been needed. Looking at obstacle course duration (Means et al., 2005), a standardized effect size was calculated to be 0.53. To achieve a significant effect for obstacle course duration, a sample size of 80 participants per group would have been needed. Therefore, for the purpose of this thesis targeting obstacle course performance, a population of 160 participants would be recruited with the expectation of seeing effects for all of the other perceived and actual balance and mobility outcome measures.

3.2 *Assignment to intervention or control group*

After providing informed consent and completing the baseline testing session, participants were randomly assigned into the intervention or control group using the simple “coin flip” randomization method (Friedman, Furberg, & DeMets, 2010). This method, compared to computer-generated random assignment, is considered fairer by participants (Means et al., 2005). As incentive, participants assigned to the intervention group received a free 12-week exercise and balance training intervention program with free parking at both the intervention (BRIC) and testing (Balance and Gait Laboratory, Welch Hall 18) locations at the university. A detailed description of the intervention program is described in Section 3.4. Participants randomly assigned to the control group were provided with the option to participate in the intervention program upon completion of the 12-week control period.

Participants assigned to either group were tested at two time points throughout the course of the study. Individuals assigned to the intervention group were tested at baseline (i.e., prior to the start of the intervention program), and 12-weeks after baseline testing (i.e., upon completion of the intervention program). Participants assigned to the control group were tested at the same time intervals as the participants in the intervention group. Throughout the 12-week interval, participants in the control group were asked to refrain from changing any aspect of their lifestyle (e.g., diet, exercise, etc.) while participants in the intervention group were asked to do the same with the primary focus on participation in the intervention program.

3.3 Experimental protocol

All experimental procedures were approved by the Brock University Research Ethics Board (REB# 11-267; Appendix A). Before the baseline testing session, participants read and signed an informed consent form (Appendix B). As part of the larger study (BASICS), participants provided demographic information, completed a randomly presented series of questionnaires focusing on psychological (e.g., body image, self-presentational concerns) and balance and movement (e.g., confidence, movement reinvestment) outcomes, had anthropometric measures taken, performed a series of balance and mobility tests, and completed fitness, strength, and flexibility tests during each of the testing sessions. The current thesis examined a portion of this dataset; measures that were examined are discussed next.

3.3.1 Demographic and anthropometric measures

Participants completed a questionnaire regarding demographic and health information (Appendix C). This self-report questionnaire was modified from one used in

the Fallproof program for older adults (Rose, 2003). Information about sex, age (years), health conditions (e.g., cardiac arrest, angina, stroke, Parkinson's disease, multiple sclerosis, rheumatoid arthritis, joint replacement, osteoporosis, etc.), medication(s), and fall history (e.g., the number of falls within the past year) obtained from this questionnaire were used to describe the pool of participants included in the dataset for this thesis. Following the completion of all questionnaires, anthropometric measures including height (cm), weight (kg), waist and hip circumference (cm), heart rate, and blood pressure were taken using standard protocols.

3.3.2 Balance confidence and movement reinvestment questionnaires

Balance confidence was assessed using the Activities-specific Balance Confidence (ABC) scale (Appendix D). It is a reliable and valid measure of balance confidence in community-dwelling older adults (Liu-Ambrose et al., 2004). It is a 16-item scale scoring the confidence a person has in maintaining balance when performing specific ADLs (Powell & Myers, 1995). The scale includes walking and reaching-oriented activities, and activities performed indoors and outdoors. The scale requires participants to rate their confidence in maintaining balance on a scale from 0% (no confidence) to 100% (complete confidence). The mean ABC score across the 16 items was used to estimate general balance confidence.

The Movement Specific Reinvestment Scale (MSRS) was used to measure the tendency for an individual to consciously control movement (Masters & Maxwell, 2008; Appendix E). The MSRS is a 10-item questionnaire, in which items are rated on a 6-point Likert scale. The MSRS is composed of two 5-item subscales; conscious motor processing (CMP) and movement self-consciousness (MSC). CMP reflects an

individual's tendency to consciously control the mechanics of movement, while MSC reflects an individual's concern over movement style (Masters & Maxwell, 2008). The mean score across the five items was calculated separately for the CMP and MSC subscales. Higher scores reflect greater CMP and MSC. The MSRS has been used to determine trait-like differences in movement reinvestment in previous studies, including older adult fallers and non-fallers (Wong et al., 2008).

3.3.3 Balance and mobility tests

Table 1 presents the five balance and mobility tests completed by each participant. The tests included the one leg stance test, normal walk test, TUG test, functional reach test, and obstacle course (OC) test. The first four tests listed are commonly used to assess level of balance performance in older adults and also are frequently used as balance outcomes when determining the effects of exercise and balance training programs on balance (Howe et al., 2011). The obstacle course test is novel to this thesis but is based on obstacle course assessment tools previously reported in the literature (Means et al., 2005; Rubenstein et al., 1997). The tests were selected to challenge different subcomponents of the balance control system required to maintain upright stance (Horak, 2006). Three trials of each test were performed during each testing session. All tests were performed in bare feet, with the exception of the functional reach and OC tests, in order to standardize balance performance across participants.

Table 1. Balance and mobility tests completed during each testing session and associated outcome measures.

Test	Trials	Dependent Measures
One leg stance	3	Mean Duration (s)
Normal walk	3	Mean Duration (s)
Timed-up-and-go (TUG)	3	Mean Duration (s)
Functional reach	3	Mean Reach Distance (cm)
Obstacle Course (OC)	3	Mean Duration (s); Mean Errors made (#)

The one leg stance test is commonly used to screen for balance problems and fall risk in older adults (Vellas et al., 1997). It has been a frequently used measure of balance in physical training studies involving older adults (Wolfson et al., 1996). It is a relevant test considering the performance of many of our ADLs require the ability to maintain balance when only one leg is on the ground (e.g., during walking, when stepping over an obstacle). Therefore, the ability to maintain single leg support is important to assess in older adults and the one leg stance test is frequently used to do this (Vellas et al., 1997). Furthermore, the one leg stance test has been used as a balance outcome measure when examining the effect of an exercise intervention on balance in older adults although with mixed results (Kamide, Shiba, & Shibata, 2009; Nelson et al., 2004; Taylor-Piliae et al., 2010; Weerdesteyn et al., 2006, Wolfson et al., 1996).

For the one leg stance test, participants stood on their preferred leg (e.g., chosen at the baseline testing session and kept constant throughout all testing sessions) while visually fixating on a target located 2.18m in front of them at eye level for the duration of the test. Participants were asked to stand for as long as they could to a maximum duration of 30s. Participants were instructed to flex the knee of the non-stance or elevated leg and maintain a 90-degree angle. These instructions were given coupled with a demonstration of the test. The spotter stood out of the participants' peripheral vision (e.g., posteriorly and to the side). In order to initiate the test, the spotter gave the option to either use their arm as a support (e.g., start in one leg stance while holding onto the spotter's arm, once ready, let go to commence test) or to get into the one leg stance position themselves without the support of the spotter. It was noted which option was used and kept constant throughout the following trials for consistency purposes. Timing of the test commenced when the participant released the support from the spotter or when they flexed the knee to raise the non-stance foot. The test was terminated if the participant rested their knees together, hooked their legs together, required support from the spotter, or changed the base-of-support (e.g., dropped the elevated leg to the ground). Compensatory arm movements (e.g., raising arms) were allowed. Three trials were performed during each testing session; mean duration (s) was used to assess performance on this test with shorter durations reflecting poorer performance.

The normal walk test is an assessment tool of mobility targeting walking velocity. Walking and mobility impairments in older adults are common (Rogers, Rogers, Takeshima, & Islam, 2003; Tinetti & Williams, 1998). Reduced walking velocity and limited mobility have been identified as risk factors for falls (Campbell, Barrier, &

Spears, 1989; Himann, Cunningham, Rechnitzer, & Paterson, 1988; Nevitt, Cummings, Kidel, & Black, 1989). Timed walks over short lengths (e.g., 8 m) can be effectively used to assess self-selected walking speed which is a good predictor of function and overall physical performance (Campbell et al., 1989; Himann et al., 1988; Nevitt et al., 1989). Further, the normal walk test has been used as a performance outcome measure examining the effect of an exercise and balance training intervention program on balance in older adults; significant improvements in walking velocity have been observed after participating in an intervention program (Wolfson et al., 1996).

For the normal walk test, participants were given instructions as well as a demonstration from the spotter. This test was performed on a firm support surface over a distance of 8m. Participants were instructed to walk at an “every day normal walking” pace (e.g., preferred pace) from a marked start and finish outlined on the ground. Participants were asked to start and stop with a 2-footed stance completely crossing the marked finish. The spotter walked out of the participant’s view (e.g., posteriorly and to the side). Timing of the test commenced on the spotters “ready, set, go” (e.g., not when the participant moved) and terminated when the participant came to a 2-footed stop completely over the marked finish line. Three trials were performed during each testing session; mean duration (s) was used to assess performance on this test with longer durations reflecting poorer performance.

The TUG test is commonly used to assess balance and provides insight into functional mobility in community-dwelling older adults (Shumway-Cook, Brauer, & Woollacott, 2000). The time taken to complete the test is strongly correlated to level of functional mobility (Podsiadlo & Richardson, 1991). Older adults who are able to

complete the TUG test in less than 14 seconds have been shown to be independent in performing ADLs (Shumway-Cook et al., 2000). Again, the TUG test is frequently used as a balance outcome measure when examining the effect of an exercise and balance training intervention program on balance in older adults with significant reductions observed in the time taken to complete the test in favour of the intervention group (Jehu et al., 2016; Liu-Ambrose et al., 2008; Schilling et al., 2009).

For the TUG test, participants were instructed to stand up from a chair without using the armrests, walk 3 meters as quickly as possible, cross the outlined end tape marked on the floor, turn around, return back to the chair as quickly as possible, and then sit back down in the same chair without using the armrests. The spotter braced the chair with their foot to eliminate any potential sliding and stop the participant from leaning back due to the backless chair used for the test. Timing of the test commenced on the spotters “ready, set, go” (e.g., not when the participant moved) and terminated when the participant made contact with the chair when sitting back down. Three trials were performed during each testing session; mean duration (s) was used to assess performance on this test with longer durations indicating poorer performance.

The functional reach test is a well-known clinical measure of dynamic balance (e.g., stability limits) developed by Duncan and colleagues (1990). Performance on the functional reach test has been associated with an increased risk of fall and frailty in older adults who are unable to reach more than 15cm (Duncan, Studensky, Chandler, & Prescott, 1992). The functional reach test has also been used as a balance outcome measure examining the effect of an exercise and balance training intervention on balance in older adults with participants in the intervention group reaching farther after

participating in the intervention (Arai et al., 2007; Ramsbottom et al., 2004; Suzuki, Kim, Yoshida, & Ishizaki, 2004; Sykes & Ling, 2004).

For the functional reach test, participants were given instructions and a demonstration from the spotter. Participants chose their preferred arm at the baseline testing session and used the same arm for future testing sessions. A measuring tape was pinned parallel to a corkboard at shoulder height of the participant's arm. Participants were instructed to stand next to, but not touching the wall and position their arm at 90 degrees of shoulder flexion with a closed fist, parallel to the measuring tape, keeping their shoulders square and in line with one another. The third metacarpal head was aligned at the start of the measuring tape (e.g., 0 cm position). Participants were instructed to reach as far as possible forward (e.g., hip flexion) without taking a step or touching the corkboard and to keep their heels on the ground and hold the final position for enough time to allow the spotter to accurately measure the end position of the third metacarpal head. Distance reached (cm) was measured. Participants had to maintain balance during the whole test (e.g., reach and return phase) or the trial was redone. Three trials were performed during each testing session; mean reach distance (cm) was used to assess performance on this test with smaller reach distances reflecting poorer performance.

The OC used in this thesis incorporated five distinct subcomponents chosen to challenge different systems and strategies used in balance and gait control (Means & O'Sullivan, 2000). Figures 1 and 2 present the OC completed by each participant. This OC is based on the functional obstacle course used in previous research assessing functional mobility and balance in older adults (Means & O'Sullivan, 2000). The

subcomponents included in the course were selected largely on the basis of environmental challenges most commonly experienced during ADLs in and around the home environment (Means & O’Sullivan, 2000). The layout and actual order of presentation of the obstacles is depicted in the schematic diagram shown in Figure 1. The OC subcomponents were as follows: tandem walking on foam support surface, walking and making adjustments to lower limb placement (e.g., altering step length and width) to contact foot targets, avoiding on ground and above ground obstacles, steering through barriers, and walking up and down stairs.

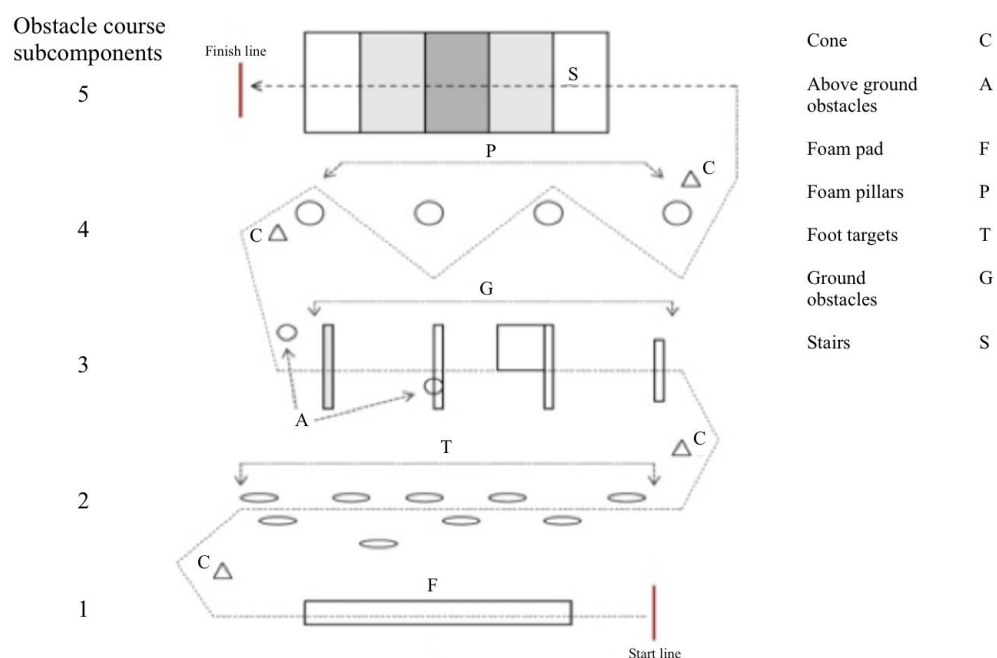


Figure 1: Schematic view of the OC and the five distinct subcomponents; tandem walking on foam support surface (1), adjusting step length and width to contact targets (2), avoiding on ground and above ground obstacles (3), steering through barriers (4), and walking up and down stairs (5).

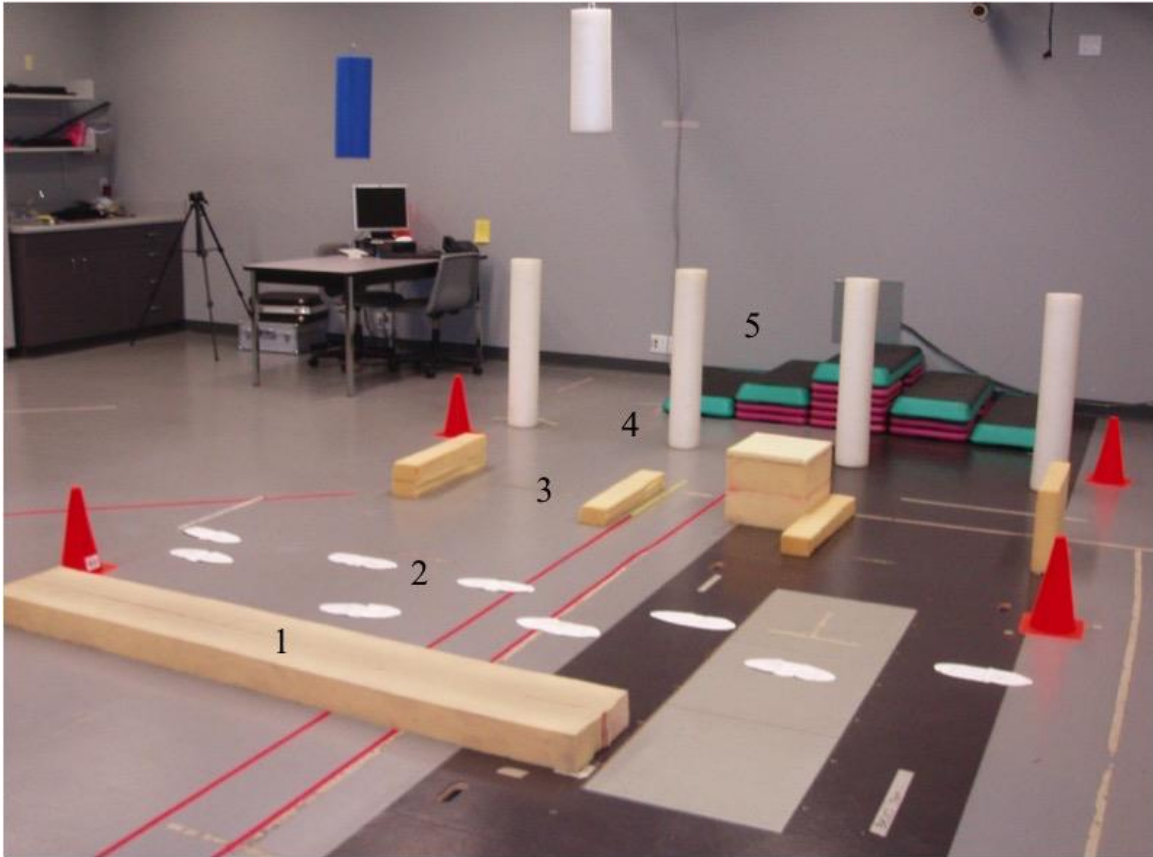


Figure 2: Camera view of the OC and the five distinct subcomponents; tandem walking on foam support surface (1), adjusting step length and width to contact targets (2), avoiding on ground and above ground obstacles (3), steering through barriers (4), and walking up and down stairs (5).

A detailed description of each OC subcomponent is discussed further in this section. Navigating through the OC equated to a linear distance of approximately 16 meters. The obstacles presented in the OC represented similar, although not identical, tasks that were used in the balance training component of the intervention program. This provided an opportunity to determine if balance training on a similar type of obstacle course layout provided a benefit to performance on the OC. Participants were given a practice trial to familiarize to the orientation and layout of the OC and to eliminate any

potential first-trial effects. Following the practice trial, participants completed 3 trials of navigating through the OC. All trials on the OC were performed in shoes. Participants were provided with rest between trials. Participants were told that a video camera would be used to record the trials that they completed on the OC. The video recorder was placed approximately 15 feet away from the participant to minimize distraction and so as not to impede progress through the OC. The tester explained and simultaneously demonstrated how each subcomponent of the OC should be completed and identified what constituted an error.

Specific instructions told to the participant were as follows: “Start with a 2-footed stance and wait for my ready, set, go mark. On my go mark, walk across the foam pad along the red line in a heel-to-toe fashion. Go around the outside of the cone coming to the outlined foot-markers. I want you to place your entire foot on the printed foot markers while walking straight ahead, avoiding missing any of the markers. Go around the outside of the cone coming to the ground foam obstacles. Pretend there are invisible walls on either side of the ground foam obstacles and I want you to avoid making contact with any ground or hanging foam obstacles, making sure you step over and within the travel path (e.g., avoid swinging leg around or outside the travel path. You can take more than one step between obstacles if you wish to do so. Go around the outside of the cone coming to the foam barriers. I want you to weave through the foam barriers starting in the direction indicated by the arrows located on the floor. Try to avoid any contact with the foam barriers. Go around the outside of the cone coming to the stairs. I want you to step up and down the stairs and finish by coming to a 2-footed stance completely past the marked finish line.”

Participants were then instructed to complete the obstacle course as quickly as possible, but being as stable as possible, and making as few errors as possible. Table 2 operationally defines what constitutes a committed error at each subcomponent of the OC. The tester clearly showed the participant what constituted an error when navigating through the OC; stepping off of the line or off of the foam pad, missing a foot-marker or not completely hitting the foot target, hitting either a ground or hanging foam obstacle, or contacting a foam barrier. If a participant committed an error, they were told to continue navigating through the OC.

Table 2. Operational definitions for errors committed on each subcomponent of the obstacle course.

Obstacle Course Subcomponent	Classifying Errors
Foam pad (1)	<ul style="list-style-type: none"> - Deviating off of the marked line - Stepping off of the foam pad - Require assistance/support from spotter
Printed foot targets (2)	<ul style="list-style-type: none"> - Missing or not fully contacting the foot targets
Above ground and on ground foam obstacles (3)	<ul style="list-style-type: none"> - Swinging limb(s) around ground foam obstacles - Contacting ground obstacles with lower limb(s) - Contacting above ground obstacles with upper extremity - Require assistance/support from spotter
Foam barriers (4)	<ul style="list-style-type: none"> - Contacting the foam barriers with any body part
Stairs (5)	<ul style="list-style-type: none"> - Tripping while walking up or down each step - Require assistance/support from spotter

The first subcomponent of the OC was the tandem walk on a foam support surface. Standing on foam requires participants to rely on the vestibular and visual systems to compensate for the reduced somatosensory information from the feet (Jeka, Kiemel, Creath, Horak, & Peterka, 2004). Participants may be unable to make compensatory adjustments to the change in support surface (Horak, Shupert, & Mirka, 1989). Manipulating the base-of-support (e.g., narrowed through tandem walk) also poses

an increased challenge to the balance control system. The dimensions of the foam used were 197 cm in length, 29 cm in width, and 9.5 cm in height.

The second subcomponent of the OC was the foot targets. There were a total of 9 outlined footprint markers placed to force different step lengths and step widths. Patla (2001) states that proactive adaptive gait strategies involve postural adjustments to an individual's movement pattern during adaptive locomotion resulting in the modification of intersegmental dynamics to maintain balance control and stability. Components of adaptive locomotion involve limb reach (e.g., step length and step width) and limb elevation (e.g., step height); it has been shown that deficits in adaptive locomotion are a combination of both components (Said, Goldie, Patla, Sparrow, & Martin, 1999). This subcomponent was designed to stress limb reach (e.g., step length and width).

The third subcomponent of the OC was on ground and above ground foam obstacles. Each ground foam obstacle was oriented in a different dimension (e.g., length, width and height). There were also two hanging obstacles (e.g., constructed by cutting a foam roller in half) placed over the third and fourth ground foam obstacle. The hanging obstacles were different in colour; the first hanging obstacle being white, the second hanging obstacle being blue. They were hung via fishing wire to a support beam located in the ceiling of the lab at a height of 143.5 cm above the ground. Both types of object negotiation maneuvers challenge the ability to incorporate visual information into the planning and performance of adaptive locomotion. Accurate and efficient visual depth perception is a critical component of this OC subcomponent. Lower limb coordination is emphasized in this OC subcomponent as stepping over ground foam obstacles challenges the balance control system by increasing the time spent on one leg. The inclusion of

hanging foam obstacles challenges the visual system by emphasizing scanning of the environment throughout adaptive locomotion. Furthermore, looking down during adaptive gait increases the chance of sustaining a fall (Zettel, Scovil, McIlroy, & Maki, 2007).

The fourth subcomponent of the OC was navigating through four foam barriers. The height of each foam barrier was 88 cm. The distance between the first and second foam barrier was the same as the distance between the third and fourth foam barrier, measuring 87 cm. The distance between the second and third foam pillar was 77 cm. This subcomponent simulates moving or steering around a stationary object that may be experienced in and around the home environment. Similarities exist between subcomponent three and subcomponent four in that both challenge the ability to integrate visual information into the planning and performance of the task(s).

The fifth subcomponent of the OC was the stairs. All participants ascended three standard type stairs and then descended three standard type stairs (e.g., 39.5 cm in length, 108 cm in width, 15 cm in height). The stairs were located adjacent to the lab wall that could be used to provide support in case a trip occurred. The ability to modify foot placement is critical for going up or down a flight of stairs (Means & O'Sullivan, 2000). In addition, muscle strength, especially in the hip flexor, hip extensor, knee extensor, and ankle plantar and dorsi flexor muscles is a key element for success in negotiating stairs.

Mean duration over the three trials on the OC (e.g., mean did not include the practice trial) was calculated in order to assess performance on the OC. Errors committed were assessed through subjective video analysis based on the operational definitions of what constitutes an error. Excluding the practice trial, every subsequent trial was video

analyzed to determine if participants committed an error on any subcomponent of the OC. The number of errors made on the five subcomponents were summed and the total number of errors were calculated for each trial. The mean number of errors across the three trials was calculated as an additional outcome measure to capture performance on the OC.

3.4 Intervention program

3.4.1 Clearance for participation in physical activity

At the baseline testing session, participants completed the Physical Activity Readiness Questionnaire (CSEP, 2002; Appendix F). This is a 7-item questionnaire, in which participants respond either yes or no to questions assessing whether they can safely increase their physical activity levels. If they answered no to all questions, it was safe for them to engage in physical activity and begin the intervention. If they answered yes to any question, or if they were over the age of 69, a note from their doctor was required stating that they were able to participate in the intervention program.

3.4.2 Summary of the intervention program

Older adults were to exercise 60-90mins per day for 3 days a week over a 12-week period. Hours of operation for participants to exercise included: Monday to Saturday from 8:00 am to 12:00 pm and Monday to Friday from 2:00 pm to 7:00 pm. There was on site supervision from trained undergraduate and graduate students who guided participants through the exercise and balance training components of the intervention. The trainers also provided encouragement and positive reinforcement to participants. The equipment available to the participants was cardiovascular equipment (e.g., treadmills, elliptical trainers, recumbent and upright bikes, rowing machine),

resistance machines (e.g., chest press, leg press, row, etc.), core equipment (e.g., mats, benches, medicine balls, stability balls), free weights (e.g., dumbbells, barbells), resistance bands, and balance equipment (e.g., full and half foam rollers, wobble boards, balance pods and discs, BOSU balls, and step platforms). The balance equipment was used to create an obstacle course setup to challenge different components of the balance control system.

Each participant tracked and monitored the exercises that they completed during each session using an exercise log sheet (Appendix G). The log sheet contained a list of exercises that the participants needed to complete during the session.

3.4.3 Orientation to the intervention program

Each participant in the intervention group attended an orientation within one week of the baseline testing session. The purpose of this orientation session was to orient the participant to the different exercise and balance training components of the intervention program, provide instruction as to how to perform the exercises and balance tasks and establish baseline levels for exercise intensities.

3.4.4 Overview of the intervention program

After completing the orientation session, participants began the intervention program. Participants attended three times per week within the flexibility of their schedule and hours of operation of the BRIC. One session lasted between 60-90 minutes. Each session is sectioned into different components with approximated time intervals for each component. Participants performed 20-30 minutes of aerobic exercise, 30-45 minutes of upper and lower body resistance training, 5-10 minutes of flexibility stretching, and 10-15 minutes of balance training. The intervention program was designed

to be progressive. Trainers increased the difficulty associated with the aerobic equipment (e.g., increased the speed or level of incline of the treadmill), the weight for resistance exercises, and provide more challenging tasks on the balance obstacle course (e.g., adding cognitive or motor challenges). The different components of the intervention program are discussed below.

3.4.4.1 Aerobic exercise

Aerobic exercise was considered as the continual movement of both upper and lower body on any chosen cardiovascular equipment that was considered of low to moderate intensity. Cardiovascular equipment in the intervention program included treadmills, recumbent bikes, stationary bikes, elliptical trainers, and rowing machines. Participants were asked to complete approximately 20-30 minutes on any of the aforementioned cardiovascular equipment while exercising at 55-85% of his/her age-related heart rate maximum ($220 - \text{age}$).

3.4.4.2 Resistance training

The strength training component of the intervention targeted all major muscle groups of the upper and lower body and was progressive in nature. Participants completed one set of 15 repetitions of the selected exercises within the muscle strengthening component of the program which included; seated chest press, seated row, leg press, triceps press down, and seated calf raises. In addition, free weights (e.g., dumbbells, barbells), resistance bands, and medicine balls were used to perform bicep curls, lateral arm raises, and squats. Core stability was another area targeted within the resistance training component. Participants performed one set of either crunches or sit and leans to target the abdominal muscles. Participants performed either cross-over

crunches or sit and twists to target the obliques. Participants also performed one set of opposite arm/leg raises to target lower back strength. All core stability exercises were performed on a standardized gym mat. The resistance training component was slightly modified in the last 6 weeks of the intervention program to incorporate more functional activities that can be practically transferred to independent living. Additions included resistance bands, weighted bars, and barbells on unstable surfaces such as exercise balls, BOSUs, and balance discs for select exercises. Progression for core stability included additional sets, or incorporating a stability/medicine ball. For muscle strengthening exercises, once participants were able to perform 15 reps of any exercise with minimal exertion, trainers increased the weight by the smallest increment that was possible. Exercises were individualized for each participant depending on individual capabilities and limitations. Alternative exercises were provided if any participant was unable to perform the given exercise.

3.4.4.3 Flexibility

Flexibility training consisted of a series of static stretches performed at the end of the training session. Stretching sessions lasted for a duration of 5-10 minutes with stretches targeting all major muscle groups (e.g., biceps, triceps, shoulders, upper back, lower back, chest, quadriceps, hamstrings, gluts, calves, and hip flexors).

3.4.4.4 Balance training

The balance training incorporated tasks and activities similar in nature to those mentioned in the OC used during the balance testing sessions. Trainers navigated the participant through self-selected balance tasks based on current balance ability; these tasks were designed to be progressive in nature increasing in difficulty during the course

of the intervention. Challenges to balance included transitions from a stable to unstable base of support, switching from two leg to one leg stance, and object manipulation while balancing. The obstacle course included a variety of unstable objects such as texturized balance pods, wobble boards, BOSUs, balance discs, and half foam rollers. To further challenge balance control, motor and cognitive tasks were added while performing basic balancing tasks on the obstacle course (e.g., verbalizing the months of the year in reverse while carrying an object on the texturized balance pods). The trainers attempted to provide progressive and fun challenges for the obstacle course component of the intervention. The balance training component of the intervention program was designed to train and target multiple subcomponents of the balance control system (Horak 2006). For example, balance tasks and activities included hand-eye and foot-eye coordination, center of mass perturbations on any support surface, base of support perturbations on a BOSU ball, holding a medicine ball during uni-pedal stance, transitioning from stairs to BOSUs, stepping over obstacle while moving a medicine ball or weighted bar around the midline of the body, and reaching tasks that involve participants to touch his/her toes or the ceiling. Participants spent approximately 10-15 minutes on the balance obstacle course.

3.5 *Statistical analysis*

Descriptive statistics (mean and standard deviation values) were calculated for demographic and anthropometric variables by group and by time (See Section 4.2; Table 5). Descriptive statistics (mean and standard deviation values) were also completed for both intervention and control groups at both time points for all perceived and actual balance and mobility outcome measures (See Section 4.4; Table 7).

To determine if there were differences between the intervention and control groups at baseline, separate one-way analysis of variance (ANOVA) procedures with participant group as the between subjects factor were conducted for all demographic and anthropometric measures.

As well, all perceived and actual balance and mobility outcome measures at baseline were submitted to a one-way ANOVA with participant group as the between subjects factor. Nine separate ANOVAs were completed; these analyses were conducted to determine if there were any significant differences for these measures between the intervention and control groups at baseline. If the intervention and control groups were different at baseline, the baseline variable(s) were entered as a covariate in a one-way ANOVA that assessed group differences at the 12-week testing session. Significance level was set to $p < 0.05$.

3.5.1 Intervention effects

To examine the effect of the exercise and balance training intervention program, separate 2 x 2 repeated-measures analyses of variance (RM-ANOVAs) were conducted for all perceived and actual balance and mobility outcome measures with the between-subject factor of group (e.g., intervention, control) and the within subject factor of time (e.g., baseline, 12-week). For any significant interaction effects, follow-up *t*-tests comparing the values between the baseline and 12 week testing sessions by group were conducted. Significance level for all of these analyses was set to $p < 0.05$. A trend was considered for *p* values between $p = 0.05$ and $p < 0.10$ and these trends were investigated.

CHAPTER FOUR: RESULTS

4.1 Data screening and statistical assumptions

Five of the 63 older adults from the larger dataset who met the inclusion criteria were removed from the final statistical analysis due to extraneous factors including physical illness/impairment that was self-reported as a health change over the course of the 12-week intervention that could have affected participation in the exercise and balance training intervention program and confounded results. After this removal, participants were age and sex matched by group. Thus, the total sample size was reduced to 46 participants (M=12, F=11 in both the intervention and control groups).

4.1.1 Outliers

All variables were screened for univariate outliers. This was done for each of the perceived and actual balance and mobility outcome measures for both the intervention and control groups at baseline and 12-week testing sessions. To check for univariate outliers, data for these variables were converted to standardized scores (z -scores). A univariate outlier was identified as having a z -score greater or less than ± 3.29 . If a variable fit this criteria, it was flagged as a potential outlying value and visually inspected to determine if the outlying value should be replaced with the next closest value in the direction it was previously outlying (Tabachnick & Fidell, 2007). For example, for the ABC mean at baseline for the control group, a z -score of -3.58 with a value of 65.63% was replaced with 78.13% as this value was the next closest in the range and is a better reflection of perceived balance performance within the group. For actual balance and mobility outcome measures, an outlying value was identified for the TUG test at the 12-week testing session for the intervention group (z -score=3.55; 12.24s). This outlying

value was replaced with 8.43s which was the next closest TUG value in the range and is a better reflection of the actual balance performance within the group. After replacements were made for each variable, data were screened again and any new cases identified as outliers were replaced using the same method (Tabachnick & Fidell, 2007). This procedure was repeated until all z -score values were within the normal distribution range and no new outliers emerged. For this thesis, only one round of replacements was needed for all perceived and actual balance and mobility measures. For the baseline testing session, only one outlier emerged in the control group. For the 12-week testing session, outliers occurred only in the intervention group. No consistent patterns for outlying values emerged across the perceived and actual balance and mobility measures (e.g., the same participant generating outlying values for different measures, or a single measure generating many outlying values). In total, there were five instances in which an outlier was identified and replaced.

4.1.2 *Normality*

Normality was assessed for all variables. This included each of the perceived and actual balance and mobility measures by group and by time. Normality was determined by examining the skewness and kurtosis statistics for each variable with significance set at $p < 0.001$. Significance was determined by converting each skewness and kurtosis statistic to a standardized z -score by dividing each value by its own standard error. Table 3 displays the skewness and kurtosis statistics for all variables examined. Any values greater or less than ± 3.29 were considered significantly skewed or kurtotic and log transformed (Field, 2009). To ensure that the dependent variable was being compared on the same scale, if one dependent variable was skewed or kurtotic, log transformations

were performed by group and time. Two dependent measures (ABC, OC duration) were skewed or kurtotic, which did not represent a normal distribution. To correct for this, log transformations were performed to meet this assumption. Due to the high negative skewness statistic for both groups at both testing sessions for ABC, the values for this measure were reverse scored (e.g., subtracted each ABC value from the highest value obtained; Field, 2009) before performing a log transformation. Both dependent variables were examined after the log transformations were completed to determine if a normal distribution was met. The new transformed data was successful in generating a normal distribution. Transformations were not required for the intervention and control groups at both baseline and 12-weeks for the following perceived and actual balance and mobility measures: CMP, MSC, one leg stance, normal walk, TUG, functional reach, and obstacle course errors. Further analyses were conducted on the original data if it was not significantly skewed and the data that required log transformations. For any dependent variable that required transformation, the results reported use the associated raw data.

Table 3. Skewness and kurtosis statistics for perceived and actual balance and mobility outcome measures by group and time.

Perceived balance values								
Intervention					Control			
Baseline		12-week			Baseline		12-week	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
ABC (%)	-2.077*	4.252*	-1.233	.484	-1.870*	3.181*	-1.564	3.126*
CMP (mean)	.276	-.839	.594	-.665	.086	-.697	-.167	-1.465
MSC (mean)	.634	-.920	1.182	.813	.650	-1.116	.357	-1.319
Actual balance values								
Baseline		12-week			Baseline		12-week	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
1 Leg (s)	.871	-5.60	.658	-.995	.684	-.380	.518	-.910
NW (s)	.194	-.116	-.158	-.834	.073	.061	-.060	-.826
TUG (s)	1.195	2.795	-.395	-.800	-.216	-.535	.942	.671
FR (cm)	.412	.289	-.182	-.508	-.371	.851	.299	-.231
OC Duration (s)	.344	-.679	.196	.030	1.669*	3.972*	.561	-.172
OC Errors (#)	-.069	-1.192	.568	.947	1.466	1.491	1.27	.349

Note: ABC=Activities-specific Balance Confidence; CMP=Conscious Motor Processing; MSC=Movement Self-Consciousness;

1 Leg=One Leg Stance; NW=Normal Walking with eyes open; TUG=Timed-Up-and-Go; FR=Functional Reach; OC=Obstacle Course

*indicates significant skewness or kurtosis with $p < 0.001$

4.1.3 Assumptions of repeated-measures analysis of variance

4.1.3.1 Homogeneity of variance

Dependent variables were individually assessed by group and by time for homogeneity of variance using the Levene's test. If the Levene's statistic was $p < 0.001$, this assumption would be violated and statistics for the row equal variances not assumed in SPSS would be reported to alter the degrees of freedom by rounding to the next whole number (Gastwirth, Gel, & Miao, 2009). All Levene's statistics were not significant.

4.1.3.2 Multicollinearity

Multicollinearity was checked by conducting Pearson bivariate correlations by group and by time for both perceived and actual balance and mobility outcome measures (Table 4). Any variables sharing a bivariate correlation greater than 0.8 ($r \geq 0.8$) were considered multicollinear (Field, 2009). None of the perceived and actual balance and mobility outcome measures exceeded this threshold.

Table 4. Bivariate correlations for perceived and actual balance and mobility outcome measures at baseline for the intervention (A) and control (B) group and at 12-weeks for the intervention (C) and control (D) groups.

A.

	2	3	4	5	6	7	8	9
1) ABC	-.121	-.197	.274	-.312	.565**	.344	-.421*	-.199
2) CMP	-	.574**	-.361	-.107	.310	-.040	.025	.168
3) MSC		-	-.259	-.083	.337	-.208	.156	-.137
4) 1 Leg			-	.171	-.398	.032	-.465*	-.147
5) NW				-	.456*	-.038	.433*	.086
6) TUG					-	-.175	.579**	.146
7) FR						-	.173	.078
8) OC Duration							-	-.090
9) OC Errors								-

B.

	2	3	4	5	6	7	8	9
1) ABC	-.236	-.476*	.106	-.190	-.295	.037	-.299	-.066
2) CMP	-	.612**	-.025	.198	.248	-.232	.197	.074
3) MSC		-	-.052	.305	.129	.065	.248	.050
4) 1 Leg			-	-.100	-.016	.183	-.301	-.190
5) NW				-	.588**	-.123	.526**	.320
6) TUG					-	-.331	.498*	.260
7) FR						-	.539**	-.388
8) OC Duration							-	.507*
9) OC Errors								-

C.

	2	3	4	5	6	7	8	9
1) ABC	-.288	-.364	.223	-.061	-.151	.075	-.194	.256
2) CMP	-	.698**	-.304	.543**	.316	-.172	.198	-.319
3) MSC		-	-.021	.069	.172	-.279	-.066	-.347
4) 1 Leg			-	-.266	-.322	-.188	-.443*	-.036
5) NW				-	.502*	-.177	.604**	.070
6) TUG					-	-.216	.672**	.023
7) FR						-	.234	.034
8) OC Duration							-	.182
9) OC Errors								-

D.

	2	3	4	5	6	7	8	9
1) ABC	.343	-.033	.249	-.036	-.036	-.275	-.013	.043
2) CMP	-	.510*	-.274	.125	.003	.120	-.109	.370
3) MSC		-	-.317	-.016	-.151	.153	-.281	.194
4) 1 Leg			-	-.318	-.454*	.186	-.404	-.487*
5) NW				-	.584**	-.040	.673**	.058
6) TUG					-	-.161	.776**	.078
7) FR						-	-.310	-.210
8) OC Duration							-	.030
9) OC Errors								-

Note: ABC=Activities-specific Balance Confidence; CMP=Conscious Motor Processing; MSC=Movement Self-

Consciousness; 1 Leg=One Leg Stance; NW=Normal Walking with eyes open; TUG=Timed-Up-and-Go;

FR=Functional Reach; OC=Obstacle Course. * $p < 0.05$; ** $p < 0.01$

4.2 *Descriptive statistics*

Descriptive statistics (mean and standard deviation values) were calculated for demographic and anthropometric variables by group and by time (Table 5). The intervention and control groups were not different in terms of demographic and anthropometric variables at baseline (all p 's>0.05). The age for those in the intervention group ranged from 65-83 years and 65-81 years for the control group. For the intervention group, three older adults experienced a fall (e.g., within the year) before starting the exercise and balance training intervention. One older adult experienced a fall episode over the 12-week duration of the intervention program. For the control group, three older adults experienced a fall (e.g., within a year) at baseline. Two older adults experienced a fall episode over the 12-week control period.

Table 5. Descriptive statistics for demographic and anthropometric variables by group and time. Mean and standard deviation values (in brackets) with the respective range below are given.

Intervention (n=23)			Control (n=23)	
Sex	M=12, F=11		M=12, F=11	
Age (yrs)	70.70 (4.67) 65-83		70.26 (4.67) 65-81	
Height (cm)	168.81 (10.46) 150.50-189.50		169.46 (9.89) 154.90-190.50	
Weight (kg)	77.78 (11.07) 50.91-91.40		81.46 (11.54) 59.90-103.73	
RHR (bpm)	71.13 (9.81) 52-97		66.57 (9.62) 48-84	
SBP (mmHg)	129.50 (13.15) 110-167		131.26 (10.93) 112-160	
DBP (mmHg)	76.23 (8.68) 60-93		75.69 (8.06) 60-92	
	Baseline	12-week	Baseline	12-week
Falls	3/23	1/23	3/23	2/23

Note: M=Male, F=Female; RHR=Resting Heart Rate; SBP=Systolic Blood Pressure; DBP=Diastolic Blood Pressure. No differences between the intervention group and control group were observed for any of the demographic or anthropometric measures.

4.3 Power and effect sizes

Post hoc power analyses and estimates of effect sizes are given for all perceived and actual balance and mobility measures for both intervention and control groups (Table 6).

Table 6. Post hoc power analyses and effect sizes for all perceived and actual balance and mobility outcome measures.

		Time main effect	Interaction effect
ABC (%)	η_p^2	.005	.072
	<i>P</i>	.076	.441
CMP (mean)	η_p^2	.006	.045
	<i>P</i>	.079	.291
MSC (mean)	η_p^2	.007	.074
	<i>P</i>	.084	.452
1 Leg (s)	η_p^2	.011	.016
	<i>P</i>	.105	.133
NW (s)	η_p^2	.375	.004
	<i>P</i>	.999	.069
TUG (s)	η_p^2	.162	.088
	<i>P</i>	.814	.522
FR (cm)	η_p^2	.057	.014
	<i>P</i>	.360	.119
OC Duration (s)	η_p^2	.197	.046
	<i>P</i>	.894	.296
OC Errors (number)	η_p^2	.174	.174
	<i>P</i>	.847	.847

Note: ABC=Activities-specific Balance Confidence; CMP=Conscious Motor Processing; MSC=Movement Self-Consciousness; 1 Leg=One Leg Stance; NW=Normal Walking with eyes open; TUG=Timed-Up-and-Go; FR=Functional Reach; OC=Obstacle Course; η_p^2 =Effect Size; *P*=Power

4.4 Intervention effects

All perceived and actual balance outcome measures were examined for any significant main effects of group and time and for any significant group by time interaction effects. The intervention and control groups were not different at baseline for all perceived and actual balance outcome measures except for the number of errors committed on the obstacle course.

Table 7. Mean (standard deviation) values for perceived and actual balance and mobility outcome measures at baseline and 12-week testing sessions for the intervention and control groups.

Perceived balance values				
Dependent measures	Intervention		Control	
	Baseline	12-week	Baseline	12-week
ABC (%)	93.75 (8.65)	96.22 (4.13)	94.91 (6.21)	93.39 (6.43)
CMP (mean)	3.08 (1.14)	2.90 (1.30)	3.07 (1.23)	3.43 (1.04)
MSC (mean)	2.29 (1.22)	1.83 (0.92)	2.35 (1.16)	2.60 (1.33)
Actual balance values				
	Intervention		Control	
	Baseline	12-week	Baseline	12-week
1 Leg (s)	13.19 (8.86)	14.74 (9.19)	14.08 (7.75)	13.93 (8.60)
NW (s)	8.24 (1.14)	7.56 (0.83)	8.27 (1.22)	7.69 (0.88)
TUG (s)	7.88 (1.34)	7.08 (0.94)	7.89 (1.27)	7.76 (1.54)
FR (cm)	35.89 (4.83)	38.57 (5.71)	34.85 (6.59)	35.79 (7.95)
OC Duration (s)	25.87 (3.55)	25.01 (4.00)	27.93 (7.26)	25.27 (5.79)
OC Errors (number)	3.39 (1.89)	1.89 (0.91)	2.27 (1.85)	2.27 (1.86)

Note: ABC=Activities-specific Balance Confidence; CMP=Conscious Motor Processing; MSC=Movement Self-Consciousness; 1 Leg=One Leg Stance; NW=Normal Walking with eyes open; TUG=Timed-Up-and-Go; FR=Functional Reach; OC=Obstacle Course

4.4.1 Perceived balance outcome measures

4.4.1.1 Balance confidence

No significant group main effect, time main effect, or group by time interaction effect was observed for balance confidence. Mean balance confidence scores at baseline and 12-week testing sessions for the intervention and control groups are presented in Table 7.

There was a trend for a significant interaction effect found for balance confidence ($F_{(1,44)} = 3.428, p=0.071$). From the follow up paired sample *t*-tests, balance confidence appeared to increase in the intervention group from the baseline to the 12-week testing

session ($t_{22}=-1.719$ $p=0.100$) while there was no change in balance confidence between the two testing sessions for the control group ($t_{22}=1.199$ $p=0.243$; Figure 3).

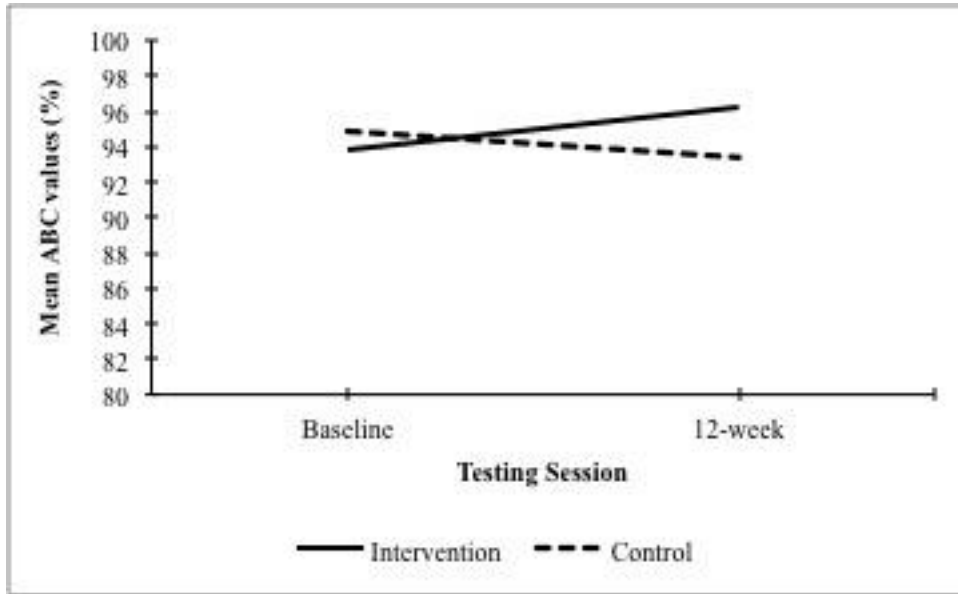


Figure 3: Mean balance confidence/ABC scores for baseline and 12-week testing sessions for the intervention and control groups. Note that there was only a trend for a significant group by time interaction effect ($p=0.071$).

4.4.1.2 Movement reinvestment (CMP, MSC)

No significant group main effect, time main effect, or group by time interaction effect was observed for CMP or MSC reinvestment. Mean CMP and MSC scores at baseline and 12-week testing sessions for the intervention and control groups are presented in Table 7.

There was a trend for a significant interaction effect observed for MSC ($F_{(1,44)} = 3.537$, $p=0.067$). From the follow up paired sample t -tests, MSC appeared to decrease at the 12-week compared to the baseline testing session in the intervention group ($t_{22}=1.818$

$p=0.083$) while there was no change in MSC between the two testing sessions for the control group ($t_{22}=-0.893$ $p=0.382$; Figure 4).

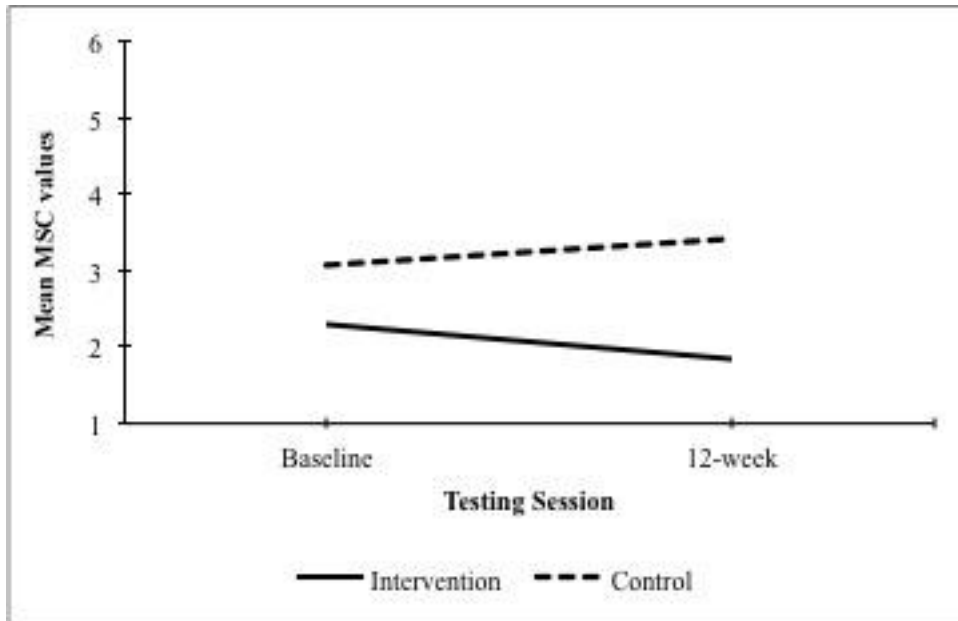


Figure 4: Mean MSC scores for baseline and 12-week testing sessions for the intervention and control groups. Note that there was only a trend for a significant group by time interaction effect ($p=0.067$).

4.4.2 Actual balance outcome measures

4.4.2.1 One leg stance

No significant group main effect, time main effect, or group by time interaction effect was observed for one leg stance duration. Mean one leg stance durations at baseline and 12-week testing sessions for the intervention and control groups are presented in Table 7.

4.4.2.2 *Normal walk*

There was a significant time main effect found for normal walk duration ($F_{(1,44)} = 26.368, p < 0.001$). The time taken to walk 8-m was significantly less at the 12-week testing session (mean \pm standard deviation: $7.63s \pm 0.86s$) compared to the baseline testing session (mean \pm standard deviation: $8.26s \pm 1.18s$) for all participants. No significant group main effect or group by time interaction effect was observed for normal walk duration. Mean normal walk durations at baseline and 12-week testing sessions for the intervention and control groups are presented in Table 7.

4.4.2.3 *Timed-up-and-go (TUG)*

A significant group by time interaction effect was found for TUG duration ($F_{(1,44)} = 4.246, p = 0.045$). Follow up-paired sample t -tests showed that the time taken to complete the TUG test was reduced at the 12-week compared to baseline testing session in the intervention group only ($t_{22} = 3.559, p = 0.002$). No change in TUG duration was observed between the two testing sessions for the control group ($t_{22} = 0.597, p = 0.556$). Mean TUG durations at baseline and 12-week testing sessions for the intervention and control groups are presented in Table 7 and shown in Figure 5.

There was a significant time main effect found for TUG duration ($F_{(1,44)} = 5.020, p = 0.006$). The time taken to complete the TUG test was significantly less at the 12-week testing session (mean \pm standard deviation: $7.42s \pm 1.24s$) compared to the baseline testing session (mean \pm standard deviation: $7.89s \pm 1.31s$) for all participants.

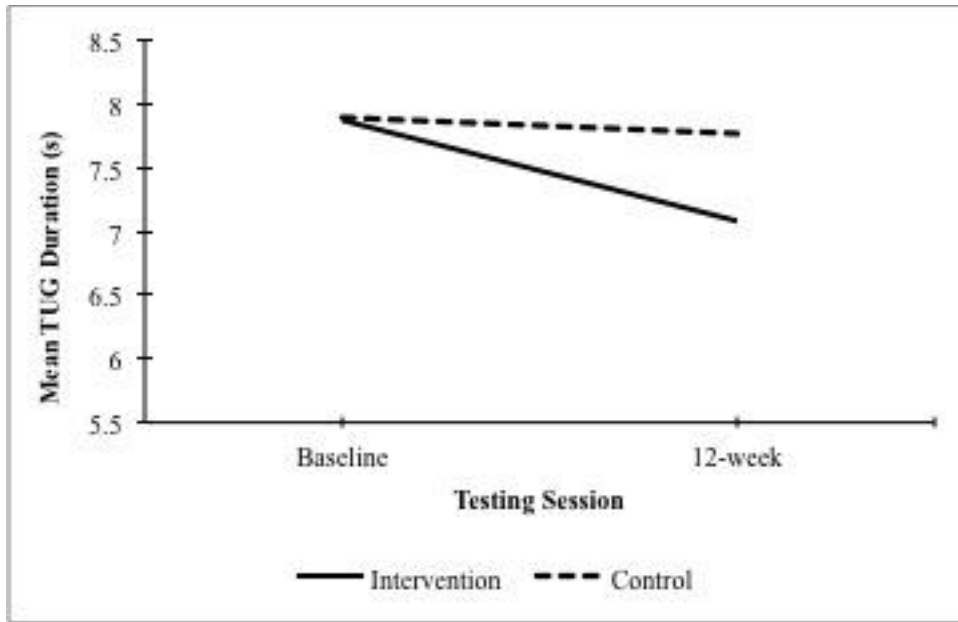


Figure 5: Mean TUG duration for baseline and 12-week testing sessions for the intervention and control groups. Note that there was a significant group by time interaction effect ($p=0.045$).

4.4.2.4 Functional reach

No significant group main effect, time main effect, or group by time interaction effect was observed for functional reach distance. Mean functional reach distances at baseline and 12-week testing sessions for the intervention and control groups are presented in Table 7.

4.4.2.5 Obstacle course

There was a significant time main effect for obstacle course duration ($F_{(1,44)} = 10.773, p=0.002$). The time taken to complete the obstacle course was significantly less at the 12-week testing session (mean \pm standard deviation: $25.14s \pm 4.90s$) compared to the baseline testing session (mean \pm standard deviation: $26.90s \pm 5.41s$) for all participants. No significant group main effect or group by time interaction effect was observed for

obstacle course duration. Mean obstacle course durations at baseline and 12-week testing sessions for the intervention and control groups are presented in Table 7.

A significant difference between the intervention and control groups at baseline was revealed for the mean number of errors committed on the obstacle course ($F_{(1,45)} = 4.102, p=0.049$). A univariate ANOVA was conducted to examine if differences existed between the intervention and control groups for obstacle course errors committed at the 12 week testing session controlling for obstacle errors committed at the baseline testing session (entered as a covariate in this analysis) After controlling for obstacle course errors at baseline which was a significant covariate ($F_{(1,43)} = 16.441, p<0.0001$), a significant group main effect was found for number of errors committed on the obstacle course at the 12-week testing session ($F_{(1,43)} = 4.642, p=0.037$). The mean number of errors made on the obstacle course at the 12-week testing session was less in the intervention group (mean \pm standard deviation: 1.89 ± 0.91) compared to the control group (mean \pm standard deviation: 2.27 ± 1.86) Mean number of obstacle course errors for the baseline and 12-week testing sessions for the intervention and control groups are presented in Table 7 and shown in Figure 6.

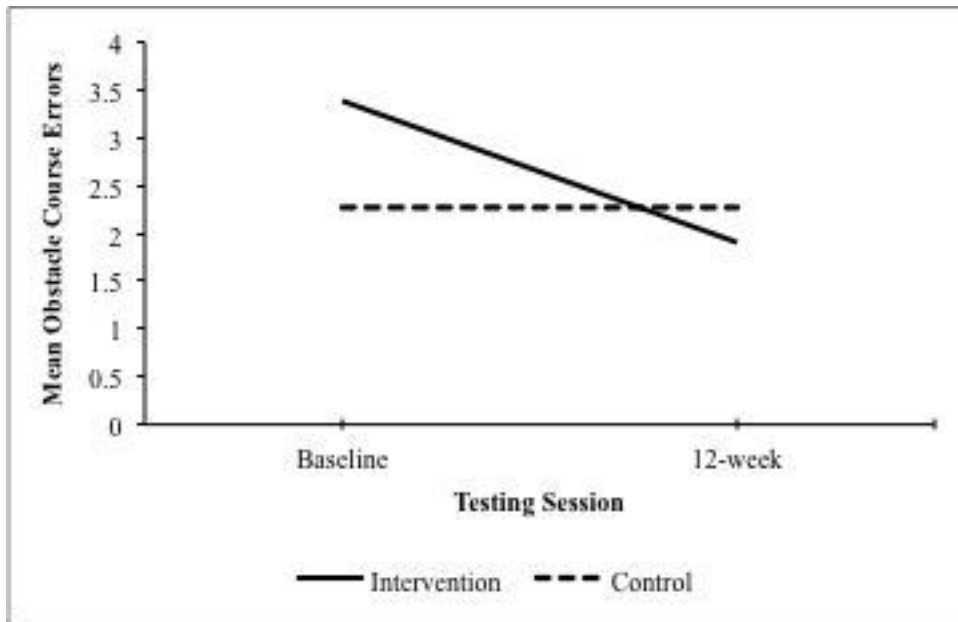


Figure 6: Mean number of obstacle course errors for baseline and 12-week testing sessions for the intervention and control groups. Note that there was a significant difference at baseline between the intervention and control group. After controlling for this, fewer errors were committed by the intervention compared to the control group at the 12-week testing session.

CHAPTER 5: DISCUSSION

The objective of this thesis was to determine the effect of a 12-week exercise and balance training intervention program on perceived and actual balance outcomes in healthy community-dwelling older adults. The intervention included aerobic exercise, upper and lower body resistance training, flexibility training and balance training. The balance training primarily used an obstacle course set-up that could be modified to provide multiple task and environmental challenges to the balance control system. The impact of the intervention program was assessed using a variety of standard as well as novel perceived and actual balance outcome measures.

It was expected that older adults in the intervention group would show improvements in perceived and actual balance outcome measures when assessed at the 12-week testing session (perceived outcomes: higher balance confidence, less conscious motor processing and movement self-consciousness reinvestment; actual outcomes: increased functional reach distances, longer one leg stance durations, shorter walk durations, shorter TUG durations, shorter obstacle course durations and fewer obstacle course errors). In contrast, it was expected that no changes in either perceived or actual balance outcome measures would be observed for participants in the control group. Support for these hypotheses would be reflected by a significant interaction between group (e.g., intervention, control) and time (e.g., baseline, 12-week testing session).

The results of this thesis provided partial support for the hypotheses with a significant effect of the intervention program observed for two (e.g., TUG duration, obstacle course errors) of the nine outcome measures. There was also a trend for a significant effect of the intervention program for two additional outcome measures (e.g.,

balance confidence, movement self-consciousness reinvestment). Individuals in the intervention group had significantly shorter TUG durations and made significantly fewer errors when completing the obstacle course at the 12-week testing session compared to the baseline testing session while individuals in the control group did not show any significant improvement in performance in these measures between the two testing sessions. Individuals in the intervention group reported higher levels of balance confidence and lower levels of movement self-consciousness reinvestment at the 12-week testing session compared to the baseline testing session while individuals in the control group had similar levels of confidence and movement self-consciousness reinvestment between the two testing sessions. No other significant interaction effect or trend for a significant interaction effect was observed. For the normal walk and obstacle course tests, only a main effect of time was observed; shorter normal walk and obstacle course durations were observed at the 12-week testing session compared to the baseline testing session for all participants. No significant main effects or interaction effect was observed for amount of conscious motor processing reinvestment, one leg stance duration and functional reach distance.

The results of this thesis showed that participating in 12 weeks of an exercise and balance training intervention program including the use of an obstacle course to train multiple components of the balance control system can effect change in select perceived and actual balance outcome measures in healthy older adults.

5.1 Characteristics of the sample at baseline

At the baseline testing session, perceived and actual balance outcome measures were similar for the intervention and control groups, except for errors made completing

the obstacle course (i.e., the intervention group committed more errors than the control group). An examination of the outcome measures assessed at baseline reveals that the sample of older adults examined in this thesis reflects a healthy and high functioning group of individuals aged 65 years of age and older. For example, average levels of balance confidence on the ABC scale are considered high for both the intervention group (94%) and the control group (95%). Of the 46 individuals in the intervention or control group, only four reported an average balance confidence score of 80 percent or less. Research has shown that older adults who report an average balance confidence score of 80% or greater on the ABC scale are highly functioning and independent (Myers, Fletcher, Myers, & Sherk, 1998). Other research has also reported average balance confidence scores ranging from 80% to 91.5% in older adults (Liu-Ambrose et al., 2004; Schepens, Goldberg, & Wallace, 2010; Schilling et al., 2009). It is likely that the exclusion criteria (e.g., presence of chronic conditions) for this thesis resulted in a sample with a high level of balance confidence. It is well known that balance confidence levels are lower in individuals with balance and mobility problems (Hatch, Gill-Body, & Portney, 2003; Myers et al., 1998).

Baseline average TUG durations were approximately 8s for both the intervention and control group with a range of 5s to 12s to complete the test across all participants. The TUG test is a common tool used to assess balance and provides insight into functional mobility levels in older adults; a range of TUG durations have been reported in the literature for different samples of older adults (Bohannon, 2006). The TUG durations for the participants in this thesis were similar to the average TUG duration (8.4s) reported by Shumway-Cook, Brauer, and Woollacott (2000) for a sample of community-dwelling

older adult non-fallers. Importantly, community-dwelling older adults who take longer than 14s to complete the TUG test have a high risk for falls (Shumway-Cook et al., 2000). In this thesis, fall rates were low and similar across intervention and control groups; only 6 of the 46 older adults or 13% reported a fall in the past year. This number is considerably lower compared to previous research which has estimated that approximately 1/3 of older adults 65 years of age or older fall each year (Rubenstein, 2006; Speechley, 2011).

Average one leg stance durations (intervention group: 13s; control group: 14s) and walk durations over 8-m (intervention group: 8s; control group: 8s) as well as functional reach distances (intervention group: 36cm; control group: 35cm) provide support that the older adults in this thesis represent healthy and highly functioning individuals (Taylor-Piliae et al., 2010; Weerdesteyn et al., 2006). Limited or no data for healthy older adults for conscious motor processing and movement self-consciousness reinvestment and for obstacle course duration and errors made on the novel obstacle course used in this thesis was available for comparison.

Overall, the examination of the perceived and actual balance outcomes at baseline provide converging evidence to support the conclusion that the sample of older adults investigated in this thesis was highly confident and had above average balance and mobility performance.

5.2 *Effect of the intervention program on perceived balance outcome measures*

5.2.1 *Balance confidence*

Low balance confidence is frequently reported by older adults and is linked to changes in balance and gait performance (Legters, 2002; Schepens et al., 2012). It has

been shown that low balance confidence can lead to activity restriction contributing to deconditioning limiting an older adults' ability to perform daily tasks (Hadjistavropoulos et al., 2012; Myers et al., 1998). Lower levels of balance confidence are associated with balance problems (Cho et al., 2004; Schepens et al. 2012) and falls (Lajoie & Gallagher, 2004) in older adults. This body of research shows the importance of identifying strategies to maintain and improve balance confidence in older adults. Participation in exercise and balance training programs may be one approach that can modify balance confidence in older adults (Büla et al., 2010; Rand et al., 2011). There are varied results within the literature showing the effects of different types of interventions on balance confidence; some studies have showed improvements while other have revealed no changes post-intervention (Büla et al., 2010; Rand et al., 2011).

The results of this thesis appear to support the research that has shown improvements in balance confidence in individuals participating in an exercise and balance training intervention program (Clemson et al., 2004; Liu-Ambrose et al., 2004; McKinley et al., 2008; Schilling et al., 2009; Ullmann et al., 2010; Weerdesteyn et al., 2006). There was a small although non-significant improvement ($p=0.10$) in balance confidence in the intervention group of 2.5% ($M=93.75\%$ to $M=96.22\%$) at the 12 week testing session and a small although non-significant 1.6% decrease ($p=0.24$) in balance confidence for the control group at the 12-week testing session ($M=94.91\%$ to $M=93.39\%$). In a previous study examining the effect of a 5-week intervention program that included balance, gait, and coordination training in an obstacle course, walking exercises and practicing fall techniques, significant differences emerged for balance confidence (Weerdesteyn et al., 2006). At the end of the intervention program, balance

confidence had improved by 3.5% in the exercise group (M=59.88% to M=63.38%), whereas the control group showed a slight decline of 1.5% across time (M=59.92% to M=58.44%). The balance confidence values reported at baseline by participants in their study were considerably lower than the values reported by participants in this thesis. However, another study showed that 5 weeks of unstable surface balance training increased balance confidence in individuals reporting high levels of confidence (Schilling et al., 2009). Mean balance confidence at baseline for all participants was reported at 91.5% out of 100%, identifying a similar sample in terms of level of balance confidence used in this thesis (Schilling et al., 2009). Mean balance confidence for the training group at baseline was 92.8% and increased to 96.6% post-intervention (Schilling et al., 2009). Despite this increase in balance confidence, there were no concurrent improvements in actual balance performance observed. Mean balance confidence for the control group at baseline was 90.1% and decreased to 89.4% post-intervention (Schilling et al., 2009). It has been noted that interventions that include strengthening and balance components while incorporating challenging ADLs are most successful in improving balance confidence (Büla et al., 2010; Rand et al., 2011).

Although research has shown improvements in balance confidence following intervention programs, these studies have used a variety of different types of training components (e.g., Tai Chi, gait, balance and mobility training, strengthening exercises, general physical activity, exer-gaming), used different training durations and have trained individuals that had significantly lower balance confidence prior to starting the intervention program (Büla et al., 2010; Rand et al., 2011). As the sample in this thesis was highly confident at the start of the intervention program, it is possible that only small

gains in balance confidence could have been observed (e.g., ceiling effect). However, research has not established the size of change needed in balance confidence to contribute to a meaningful change in actual balance performance. Thus, the results of this thesis show that the exercise and balance training intervention program was successful in at least maintaining balance confidence levels and producing small gains in balance confidence among highly-functioning older adults.

5.2.2 *Movement reinvestment (CMP, MSC)*

According to the theory of reinvestment (Masters & Maxwell, 2008), individuals scoring higher on the conscious motor processing or movement self-consciousness subscales of the MSRS have a greater tendency to reinvest or direct attention toward the control and/or perception of their movements. Conscious motor processing identifies the amount of reinvestment in the mechanics of movement while movement self-consciousness shows the amount of concern one has about one's own movement style (Masters & Maxwell, 2008). It is known that a greater propensity to reinvest in movement negatively influences performance across a wide variety of skills and different population groups (Masters & Maxwell, 2008). For example, individuals with stroke or with Parkinson's disease have a greater propensity for reinvestment both in terms of conscious motor processing and movement self-consciousness compared to controls (Masters, Pall, MacMahon, & Eves, 2007; Orrell, Masters, & Eves, 2009). Elderly fallers also scored significantly higher on both conscious motor processing and movement self-consciousness reinvestment than those who had not fallen (Wong et al., 2008).

Due to limited research, it is currently unknown how an exercise and balance training intervention program will influence movement reinvestment. Contrary to the

hypothesis that conscious motor processing reinvestment would decrease at the 12-week testing session compared to the baseline testing session in the intervention group, the results of this thesis revealed no change in this measure. One explanation is that the conscious motor processing reinvestment may not have been modifiable through participation in the exercise and balance training intervention program. Research has shown that the tendency for this type of reinvestment occurs in individuals with balance impairments (Masters et al., 2007; Orrell et al., 2009); thus the effect may not have been observed in the healthy high functioning older adults studied in this thesis. Alternatively, the expected decrease in conscious motor processing reinvestment expected through participation in the intervention program may have been countered by the nature of the instructions used to focus on stability when performing the balance training component of the intervention program.

The results of this thesis showed that there appeared to be a decrease in movement self-consciousness in the intervention group of 20% ($M=2.29$ to $M=1.83$) at the 12 week testing session compared to the baseline testing session. Although movement self-consciousness reinvestment values were moving in the direction that was expected, these changes between the baseline and 12-week testing sessions for the intervention group did not reach significance. However, it is possible that the participation in the intervention program which included student trainers supervising aerobic exercise, upper and lower body strength training, flexibility training and balance training and other participants training at the same site may have reduced the tendency to reinvest in movement style. Individuals who had participated in the intervention program may have felt more

comfortable and had less concern about their movement style as the program progressed and then when again completing the assessments at the 12-week testing session.

5.3 Effect of the intervention program on actual balance outcome measures

5.3.1 Timed-up-and-go (TUG) performance

The TUG test is a commonly used assessment tool for balance control and is linked to functional mobility. The loss of functional mobility can have serious implications for older adults including loss of independence, reduced quality of life, activity restriction and increased risk of falls (Legters, 2002; Speechley, 2011). Bohannon (2006) has established normative data for the TUG in community-dwelling older adults. It was revealed that older adults between the ages of 60-69 years should have a mean TUG duration of 8.1s, 9.2s for older adults between the ages of 70-79 years, and 11.3s for older adults between the ages of 80-99 years. Given the association of TUG duration with functional mobility, it is important to identify strategies to maintain and improve TUG performance in older adults. TUG performance has been used in past research to determine if participation in an exercise and balance training program was able to modify functional balance in older adults. There have been mixed findings with respect to whether balance training improves functional mobility as measured by the TUG (Howe et al., 2011).

The results of this thesis appear to support the research that has shown improvements in functional mobility in individuals participating in an exercise and balance training intervention program (Jehu et al., 2016; Liu-Ambrose et al., 2008; Schilling et al., 2009). A significant interaction effect was found for the TUG test. At baseline, TUG scores were very similar for both groups (intervention: 7.88s; control:

7.89s). After the 12-week testing session, TUG duration had shown a significant improvement in the intervention group (M: 7.08s) and no change in the control group (M: 7.76s). An average decrease in TUG duration of $0.8s \pm 0.5s$ has been reported to be a significant change in functional mobility through home-based resistance exercise training programs (Thiebaud, Funk, Abe, 2014). It has been noted that a significant reduction observed immediately post-intervention in the time to complete the TUG test for an exercise group is 0.82s for an intervention program that uses gait, balance, co-ordination and functional tasks (Howe et al., 2011). When comparing baseline to the 12-week testing session, the intervention group showed a 0.8s reduction in TUG duration. This supports past research and suggests that significant improvements were shown in functional mobility following the exercise and balance training intervention program used in this thesis (Howe et al., 2011; Thiebaud et al., 2014).

5.3.2 *Obstacle course performance*

An obstacle course was used in this thesis to assess balance and mobility across a number of different tasks and environmental challenges. The course was continuous but included five distinct sections or components. The course design was modified based on previous research using obstacle courses to assess balance performance. The results of the thesis showed that the time taken to complete the obstacle course was shorter for all participants independent of group. However, older adults in the intervention group committed significantly fewer errors on the obstacle course at the 12-week testing session compared to the control group when taking into account the number of errors committed at baseline.

Through the limited research incorporating an obstacle course set-up to both train and assess balance control, the results of this thesis support previous studies targeting obstacle course performance (Means, Rodell, & O'Sullivan, 2005; Rubenstein et al., 1997; Weerdesteyn et al., 2006). Previous studies (Means, Rodell, & O'Sullivan, 2005; Rubenstein et al., 1997) inferred obstacle course performance through a quality-based measure. The quality scoring was developed based on the types of quality errors a participant could make as they navigated through each component of the obstacle course. Consistent with the results shown in the current thesis (fewer errors reflecting better performance), Means and colleagues (2005) found significant improvements on obstacle course quality performance. Upon completion of the intervention that included stretching, endurance walking, balance, coordination, and strengthening exercises, older adults in the exercise group significantly outperformed those in the control group. From baseline to post-intervention, the quality performance score on the obstacle course improved 2.1% for the exercise group compared with 0.3% for the control group. The results of this thesis show a 44% decrease in committing an error on the obstacle course compared to a zero percent change observed in the control group from baseline to 12-week. The minimal percentage change seen on obstacle course quality performance by Means and colleagues (2005), albeit significant, may be due to the nature of the intervention program. The intervention program consisted of 6-weeks of supervised stretching, balance, endurance, coordination, and strengthening exercises. The gold standard for any balance and exercise intervention should be no less than 12-weeks in duration to see improvements in balance control (Lesinski et al., 2015). If the intervention duration was

extended to 12-weeks, Means and colleagues (2005) could have potentially observed greater differences for obstacle course quality performance between groups.

Rubenstein and colleagues (1997) divided subjects into two groups, consisting of lower and higher functioning groups to determine which participants showed the greatest improvement over time on obstacle course performance. Obstacle course quality scores showed significant improvement among the most impaired subjects (e.g., lower functioning) while no change was shown over time among high functioning subjects following a 12-week intervention. The improvements shown in the current thesis on obstacle course performance are generalized to higher functioning older adults supporting the specificity of training within the balance-training component of the intervention. Despite the relatively high functioning sample, targeting all aspects of the balance control subsystems and the constraints involved during the intervention supports the transfer of performance on an obstacle course. Therefore, training all aspects of balance control as outlined by Horak (2006) can assist older adults in real-life scenarios reducing the potential for sustaining a fall. On the contrary, extending Fitt's Law to obstacle avoidance (Jax, Rosenbaum, & Vaughan, 2007), it would not be advisable to instruct participants to complete the obstacle course as quickly as possible. Knowing the relationship between speed and accuracy, it is possible that participants improved their obstacle course duration score at the cost of committing more errors in obstacle course performance.

Significant main effects for time (changes at the 12-week testing session compared to the baseline testing session for test duration or the time to complete the test) were found for normal walk duration ($p < 0.001$), and obstacle course duration ($p < 0.005$). The significant time main effects demonstrate that the improvements in completing the

aforementioned two balance tests were similar for the intervention group and the control group. An explanation for the observed results can be interpreted that the intervention program had no effect on walking and obstacle course performance as both groups showed the same improvement over the 12-week time period between tests. The improvements observed in both groups for these two actual balance tests could suggest the presence of a learning effect. Over the course of the study, older adults may have been more comfortable with the testing and experimental protocol. It is also unlikely that these improvements in time in both intervention and control group can be credited to improvements in balance confidence as there were no significant changes observed from the baseline to 12-week testing session.

5.3.3 One leg stance and functional reach

The lack of significant changes observed in the remaining balance tests (e.g., one legged stance, functional reach) is consistent with previous research (Taylor-Piliae et al., 2010; Weerdesteyn et al., 2006). It is possible that given the relatively healthy nature of the population examined in the thesis that the one leg stance and functional reach tests were too variable to show improvement in the intervention group following the exercise and balance intervention program. It could also be argued that the intervention program did not specifically train standing on one leg or reaching forwards past his/her stability limits or the training was of inadequate duration to transfer over and observe noticeable differences in balance control on these balance tests.

5.4 *Strengths and limitations*

5.4.1 *Sample*

The results of this thesis are generalizable only to healthy, confident, high functioning, independent, community-dwelling older adults. Different results may have been observed if the sample had included older adults with lower levels of balance confidence or poorer balance and mobility performance. Also, the impact of the exercise and balance training intervention program cannot be generalized to individuals with balance and mobility impairments such as neurological (e.g., Parkinson's disease, multiple sclerosis, stroke), musculoskeletal (e.g., joint replacement) or sensory deficits (e.g., diabetes).

The sample size for the intervention and control groups in this thesis may have been a limitation. With a larger sample size, the trends observed for balance confidence and movement self-consciousness reinvestment may have reached significance. Based on a priori and post hoc estimates of sample size, the thesis is underpowered and may have been unable to detect changes for the majority of balance outcome measures.

Despite the homogeneity of the sample of older adults in this thesis, participants may have had different age-related deficits in one or more of the subsystems involved in maintaining balance. Age-related changes in balance control influencing the different subcomponents involved in balance control may not have resulted in global and consistent changes across all older adults. For example, some older adults may have had underlying problems in sensory strategies while others may have had problems in cognitive processing (Horak 2006). For older adults in the intervention group, these

potential age-related differences may have impacted the response to the exercise and balance training intervention program.

5.4.2 Balance testing

The data presented in this thesis was taken from a dataset from a study conducted over a period of several years. One limitation is that a large number of individuals were involved in collecting data for the study and in administering the exercise and balance training program. Despite consistency in training these individuals, inter- and intra-tester reliability for balance assessment at baseline and 12-week testing sessions may be a limitation that could have impacted some of the balance assessment outcome measures (e.g., obstacle course). As well, variability in the supervision of the older adults during the exercise and balance training components of the intervention program may have limited the results of the thesis.

One observation from the results of this thesis is that the control group did show improvements in some balance outcome measures resulting in observations of a significant main effect of time (instead of a possible interaction effect between group and time). The improvements in the control group may be explained by a potential practice or learning effect as the older adults may have become more familiar with the balance tests at the 12-week testing session compared to the baseline testing session. Older adults in the control group were instructed to restrain from making lifestyle changes between the baseline and 12-week testing sessions. However, it is possible that the older adults modified certain aspects of their lifestyle (e.g., exercising more often) in preparation for committing to exercise 3 times per week which was an option for the individuals in the control group.

5.4.3 *Intervention program*

While the intervention program was standardized for all participants in the intervention group, variations were implemented (e.g., specific exercises, repetitions, intensity) to accommodate individual limitations and preferences. Due to the variations within the intervention program, each participant had an individualized program based on their capabilities. As previously mentioned, an older adult may have had deficits in one or more of the balance subcomponents involved in overall balance control (Horak, 2006). Over the duration of the intervention program, some older adults may have benefited from certain aspects of the training program, while other older adults may have experienced minimal to no changes in balance control due to the training program (e.g. potential for ceiling or floor effects on the balance outcome measures that were assessed). Individual differences in the progression of improvement during the training program may have contributed to increased variability in response to the intervention program. The intervention program encompassed multiple facets of training; some participants may have shown marked improvements in one component (e.g., strength) but not as much improvement in others (e.g., balance) depending on their compliance with the different aspects of the program. For example, it is possible that some participants in the intervention group may have been much more motivated to participate and complete each component of the training program, putting forth more effort compared to others. Conversely, perhaps some older adults were not invested in the program and may not have completed the required components.

It is possible that the length of the training program (12-weeks) may have been of inadequate duration to produce changes in balance control. Adhering to the rules of

structuring a gold standard balance training program (e.g., 90-120 min of balance training per week) for older adults (Lesinski et al., 2015), it is possible that participants were not subjected to enough balance (e.g., obstacle course) training in the intervention program. Also, although not examined in this thesis, it is possible adherence to the exercise program may have limited the benefit of the exercise and balance training intervention program.

Another possible limitation is the perceived and actual balance outcome tests and measures used to quantify changes in balance to the exercise and balance training intervention program. One strength of this thesis is that a number of different perceived and actual balance outcome tests and measures were implemented to assess the impact of the intervention program with the intervention program resulting in changes to some of these measures. However, it is always difficult to select the type of balance test and measure to assess the balance control system. Examining the Cochrane review by Howe and colleagues (2011), many different types of tests and outcome measures have been used to assess the impact of an exercise and balance training intervention. Many of the tests selected were standard clinical tools used to assess balance in older adults; however, due to the healthy older adults studied in the current thesis it is possible that these tests and measures were not sensitive to detect changes with the intervention program. Due to the complexity of the balance control system, it is possible that performance on different types of balance tests and challenges may have yielded different results. For example, more detailed quantification of performance on the tests (e.g., wearable technology such as accelerometers) used in this thesis may have been able to reveal changes in balance

strategy that could not be detected using more outcome based measures (e.g., duration, errors made on the obstacle course).

5.5 *Future directions*

Considering the aforementioned strengths and limitations, some recommendations can be made based on the results of this thesis for future research direction. To benefit the obstacle course as an assessment tool for balance control, it is recommended to examine each of the five subcomponents independently for duration and errors made instead of using a global duration and error measure on obstacle course performance. Also, by separating the obstacle course into its distinct subcomponents, we can then target what aspects of the obstacle course are most problematic for older adults and emphasize that deficit during the balance training. Also, considering how high functioning the sample population is, it may be beneficial for future studies to increase the difficulty in balance training during the intervention. Through the progressive nature of the balance component and the practice involved, participants may have surpassed the difficulty level presented when completing the balance course testing procedure at the 12-week testing session. Despite the inclusion of an obstacle course to adequately assess the multiple components of balance control to mimic real life scenarios, it is still a closed environment and lacks the unpredictability of navigating in the outside world. It does not truly simulate real-life environmental challenges that one can potentially encounter in the community and may not transfer over to everyday life.

The inclusion of more quantitative data (e.g., trunk sway) over and above the dependent measures involved with this thesis can provide better insight into the movement strategies that older adults may exhibit when navigating through an obstacle

course. It is recommended that a follow-up study be conducted to determine the ongoing effects of the program. It would be interesting to determine if the benefits of the exercise and balance training intervention (e.g., shorter TUG scores, reduced obstacle course errors) persisted in the intervention group compared to the control group. Future studies involving obstacle course performance should include lower functioning older adults to determine the efficacy of this type of program on these individuals.

5.6 *Conclusions*

This thesis was the first to investigate the effects of an exercise and balance training intervention that used an obstacle course designed to target multiple aspects of balance control to train and assess functional balance and mobility in older adults. This thesis provides evidence that using an obstacle course for both training and assessing balance control with tailored subcomponents to target all aspects of balance control can have a positive effect on older adults' functional balance and mobility. Therefore, knowing how useful an obstacle course can be as a functional balance and mobility tool, it has the potential to assist clinicians in identifying older adults at risk of falling and designing future intervention programs.

REFERENCES

- Arai, T., Obuchi, S., Inaba, Y., Nagasawa, H., Shiba, Y., Watanabe, S., & Kojima, M. (2007). The effects of short-term exercise intervention on falls self-efficacy and the relationship between changes in physical function and falls self-efficacy in Japanese older people: a randomized controlled trial. *American Journal of Physical Medicine & Rehabilitation*, 86, 133-141.
- Büla, C.J., Monod, S., Hoskovec, C., & Rochat, S. (2010). Interventions aiming at balance confidence improvement in older adults: an updated review. *Gerontology*, 57, 276-286.
- Bohannon, R.W. (2006). Reference values for the timed up and go test: a descriptive meta-analysis. *Journal of Geriatric Physical Therapy*, 29(2), 64-68.
- Campbell, A.J., Borrie, M.J., & Spears, G.F. (1989). Risk factors for falls in a community-based prospective study of people 70 years and older. *Journal of Gerontology*, 44, M112-M117.
- Clemson, L., Cumming, R.G., Kendig, H., Swann, M., Heard, R., & Taylor, K. (2004). The effectiveness of a community-based program for reducing the incidence of falls in the elderly: a randomized trial. *Journal of the American Geriatrics Society*, 52, 1487-1494.
- Cohen, J. (1988). *Statistical power analysis for the behavioural sciences*. Hillsdale: Lawrence Erlbaum Associates.
- Canadian Society for Exercise Physiology. (2002). PAR-Q & You. *CSEP*.
- Cho, B. L., Scarpace, D., & Alexander, N. B. (2004). Tests of stepping as indicators of mobility, balance, and fall risk in balance-impaired older adults. *Journal of the American Geriatrics Society*, 52, 1168-1173.
- Duncan, P.W., Studenski, S., Chandler, J., & Prescott, B. (1992). Functional reach: predictive validity in a sample of elderly male veterans. *Journal of Gerontology*, 47, M93-M98.
- Duncan, P.W., Weiner, D.K., Chandler, J., & Studenski, S. (1990). Functional reach: a new clinical measure of balance. *Journal of Gerontology*, 45, M192-M197.
- Field, A. (2009). *Discovering statistics using SPSS*. Sage Publications. London.
- Friedman, L.M., Furberg, C.D., & DeMets, D.L. (2010). The randomization process. In *Fundamentals of Clinical Trials* (pp. 97-117). Springer New York.

- Gastwirth, J.L., Gel, Y.R., & Miao, W. (2009). The impact of Levene's test of equality of variances on statistical theory and practice. *Statistical Science*, 24, 343-360.
- Hadjistavropoulos, T., Carleton, R.N., Delbaere, K., Barden, J., Zwakhalen, S., Fitzgerald, B., & Hadjistavropoulos, H. (2012). The relationship of fear of falling and balance confidence with balance and dual tasking performance. *Psychology and Aging*, 27, 1-13.
- Hatch, J., Gill-Body, K.M., & Portney, L.G. (2003). Determinants of balance confidence in community-dwelling elderly people. *Physical Therapy*, 83, 1072-1079.
- Himann, J.E., Cunningham, D.A., Rechnitzer, P.A., & Paterson, D.H. (1988). Age-related changes in speed of walking. *Medicine and Science in Sports and Exercise*, 20, 161-166.
- Horak, F.B. (2006). Postural orientation and equilibrium: What we need to know about neural control of balance to prevent falls? *Age and Ageing*, 35, ii7-ii11.
- Horak, F.B., Shupert, C.L., & Mirka, A. (1989). Components of postural dyscontrol in the elderly: a review. *Neurobiology of Aging*, 10, 727-738.
- Howe, T.E, Rochester, L, Neil, F, Skelton, D.A, Ballinger, C. Exercise for improving balance in older people. Cochrane Database of Systematic Reviews 2011, Issue 11. Art. No.: CD004963.
- Huxham, F.E., Goldie, P.A., & Patla, A.E. (2001). Theoretical considerations in balance assessment. *Australian Journal of Physiotherapy*, 47, 89-100.
- Jax, S.A., Rosenbaum, D.A., & Vaughan, J. (2007). Extending Flitts' Law to manual obstacle avoidance. *Experimental Brain Research*, 180, 775-779.
- Jehu, D.A., Paquet, N., & Lajoie, Y. (2016). Balance and mobility training with or without concurrent cognitive training improves the timed up and go (TUG), TUG cognitive, and TUG manual in healthy older adults: an exploratory study. *Aging Clinical and Experimental Research*, 1-10.
- Jeka, J., Kiemel, T., Creath, R., Horak, F., & Peterka, R. (2004). Controlling human upright posture: velocity information is more accurate than position or acceleration. *Journal of Neurophysiology*, 92, 2368-2379.
- Kamide, N., Shiba, Y., & Shibata, H. (2009). Effects on balance, falls, and bone mineral density of a home-based exercise program without home visits in community dwelling elderly women: a randomized controlled trial. *Journal of Physiological Anthropology*, 28, 115-122.

- Lajoie, Y., & Gallagher, S. (2004). Predicting falls within the elderly community: comparison of postural sway, reaction time, the Berg balance scale and the Activities-specific Balance Confidence (ABC) scale for comparing fallers and non-fallers. *Archives of Gerontology and Geriatrics*, 38, 11-26.
- Legters, K. (2002). Fear of falling. *Physical Therapy*, 82, 264-272.
- Lesinski, M., Hortobágyi, T., Muehlbauer, T., Gollhofer, A., & Granacher, U. (2015). Effects of balance training on balance performance in healthy older adults: a systematic review and meta-analysis. *Sports Medicine*, 45, 1721-1738.
- Liu-Ambrose, T., Donaldson, M.G., Ahamed, Y., Graf, P., Cook, W.L., Close, J., Lord, S.R. and Khan, K.M. (2008), Otago home-based strength and balance retraining improves executive functioning in older fallers: a randomized controlled trial. *Journal of the American Geriatrics Society*, 56, 1821–1830.
- Liu-Ambrose, T., Khan, K.M., Eng, J.J., Lord, S.R., & McKay, H.A. (2004). Balance confidence improves with resistance or agility training. *Gerontology*, 50, 373-382.
- Lord, S.R., Sherrington, C., Menz, H.B., & Close, J. (2007). Falls in older people; risk factors and strategies for prevention. *Cambridge University Press, New York*.
- Lord, S.R., Ward, J., Williams, P., & Strudwick, M. (1995). The effect of a 12-month exercise trial on balance, strength, and falls in older women: A randomized controlled trial. *Journal of the American Geriatrics Society*, 43, 1198-1206. .
- Maki, B.E., & McIlroy, W.E. (1996). Postural control in the older adult. *Clinics in Geriatric Medicine*, 12, 635-658.
- Masters, R., Eves, F., & Maxwell, J.P. (2005). Development of a movement specific reinvestment scale. *International Society of Sport Psychology*, Sydney, Australia.
- Masters, R., & Maxwell, J.P. (2008). The theory of reinvestment. *International Review of Sport and Exercise Psychology*, 1, 160–183.
- Masters, R.S., Pall, H.S., MacMahon, M.A., & Eves, F.F. (2007). Duration of Parkinson disease is associated with an increased propensity for reinvestment. *Neurorehabilitation and Neural Repair*, 21, 123-126.
- McKinley, P., Jacobson, A., Leroux, A., Bednarczyk, V., Rossignol, M., & Fung, J. (2008). Effect of a community-based Argentine tango dance program on functional balance and confidence in older adults. *Journal of Aging and Physical Activity*, 16, 435-453.

- Means, K.M. (1996). The obstacle course: a tool for the assessment of functional balance and mobility in the elderly. *Journal of Rehabilitation Research and Development*, 33, 413-428.
- Means, K.M., & O'Sullivan, P.S. (2000). Modifying a functional obstacle course to test balance and mobility in the community. *Journal of Rehabilitation Research and Development*, 37, 621-632.
- Means, K.M., Rodell, D.E., O'Sullivan, P.S. (1996). Use of an obstacle course to assess balance and mobility in the elderly: A validation study. *American Journal of Physical Medicine & Rehabilitation*, 75, 88-95.
- Means, K.M., Rodell, D.E., & O'Sullivan, P.S. (2005). Balance, mobility, and falls among community-dwelling elderly persons: effects of a rehabilitation exercise program. *American Journal of Physical Medicine & Rehabilitation*, 84, 238-250.
- Means, K.M., Rodell, D.E., O'Sullivan, P.S., & Winger, R.M. (1998). Comparison of a functional obstacle course with an index of clinical gait and balance and postural sway. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 53, M331-M336.
- Myers, A., Fletcher, P., Myers, A., & Sherk, W. (1998). Discriminative and evaluative properties of the activities-specific balance confidence (ABC) scale. *Journal of Gerontology*, 53, 287-294.
- Nelson, M.E., Layne, J.E., Bernstein, M.J., Nuernberger, A., Castaneda, C., Kaliton, D., & Singh, M.A.F. (2004). The effects of multidimensional home-based exercise on functional performance in elderly people. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 59, M154-M160.
- Nevitt, M.C., Cummings, S.R., Kidd, S., & Black, D. (1989). Risk factors for recurrent nonsyncopal falls: a prospective study. *The Journal of the American Medical Association*, 261, 2663-2668.
- Orrell, A.J., Masters, R.S.W., & Eves, F.F. (2009). Reinvestment and movement disruption following stroke. *Neurorehabilitation and Neural Repair*, 23, 177-183.
- Patla, A.E. (1995). A framework for understanding mobility problems in the elderly. *Gait Analysis: Theory and Application*, 436-449.
- Patla, A.E. (1997). Understanding the roles of vision in the control of human locomotion. *Gait & Posture*, 5, 54-69.

- Patla, A.E. (2001). Mobility in complex environments: implications for clinical assessment and rehabilitation. *Journal of Neurologic Physical Therapy*, 25, 82-90.
- Podsiadlo, D., & Richardson, S. (1991). The timed "Up & Go": a test of basic functional mobility for frail elderly persons. *Journal of the American Geriatrics Society*, 39, 142-148.
- Powell, L.E., & Myers, A.M. (1995). The Activities-specific Balance Confidence (ABC) Scale. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, 50A, M28-34.
- Ramsbottom, R., Ambler, A., Potter, J., Jordan, B., Nevill, A., & Williams, C. (2004). The effect of 6 months training on leg power, balance, and functional mobility of independently living adults over 70 years old. *Journal of Aging and Physical Activity*, 12, 497-510.
- Rand, D., Miller, W.C., Yiu, J., & Eng, J.J. (2011). Interventions for addressing low balance confidence in older adults: a systematic review and meta-analysis. *Age and Ageing*, 40, 297-306.
- Reelick, M.F., van Ersele, M.B., Kessels, R.C., & Olde Rikkert, M.M. (2009). The influence of fear of falling on gait and balance in older people. *Age and Ageing*, 38, 435-440.
- Rogers, M.E., Rogers, N.L., Takeshima, N., & Islam, M.M. (2003). Methods to assess and improve the physical parameters associated with fall risk in older adults. *Preventive Medicine*, 36, 255-264.
- Rose, D.J. (2003). *Fallproof!:* a comprehensive balance and mobility training program. *Human Kinetics*.
- Rubenstein, L.Z. (2006). Falls in older people: epidemiology, risk factors and strategies for prevention. *Age and Ageing*, 35, 37-41.
- Rubenstein, L.Z., Josephson, K.R., Trueblood, P.R., Yeung, K., Harker, J.O., & Robbins, A.S. (1997). The reliability and validity of an obstacle course as a measure of gait and balance in older adults. *Aging Clinical and Experimental Research*, 9, 127-135.
- Said, C.M., Goldie, P.A., Patla, A.E., Sparrow, W.A., & Martin, K.E. (1999). Obstacle crossing in subjects with stroke. *Archives of Physical Medicine and Rehabilitation*, 80, 1054-1059.
- Schepens, S., Goldberg, A., & Wallace, M. (2010). The short version of the Activities specific Balance Confidence (ABC) scale: Its validity, reliability, and relationship

- to balance impairment and falls in older adults. *Archives of Gerontology & Geriatrics*, 51, 9-12.
- Schepens, S., Sen, A., Painter, J.A., & Murphy, S.L. (2012). Relationship between fall related efficacy and activity engagement in community-dwelling older adults: A meta-analytic review. *American Journal of Occupational Therapy*, 66, 137148.
- Schilling, B.K., Falvo, M.J., Karlage, R.E., Weiss, L.W., Lohnes, C.A., & Chiu, L.Z. (2009). Effects of unstable surface training on measures of balance in older adults. *The Journal of Strength & Conditioning Research*, 23, 1211-1216.
- Shumway-Cook, A., Brauer, S., & Woollacott, M. (2000). Predicting the probability for falls in community-dwelling older adults using the Timed Up & Go Test. *Physical Therapy*, 80, 896-903.
- Shumway-Cook, A., Patla, A.E., Stewart, A., Ferrucci, L., Ciol, M.A., & Guralnik, J.M. (2002). Environmental demands associated with community mobility in older adults with and without mobility disabilities. *Physical Therapy*, 82, 670-681.
- Speechley, M. (2011). Unintentional falls in older adults: a methodological historical review. *Canadian Journal on Aging*, 30, 21-32.
- Statistics Canada. (2014). Seniors' falls in Canada; second report. *Public Health Agency of Canada*, 1-53.
- Sturnieks, D.L., St George, R., & Lord, S.R. (2008). Balance disorders in the elderly. *Clinical Neurophysiology*, 38, 467-478.
- Suzuki, T., Kim, H., Yoshida, H., & Ishizaki, T. (2004). Randomized controlled trial of exercise intervention for the prevention of falls in community-dwelling elderly Japanese women. *Journal of bone and mineral metabolism*, 22, 602-611.
- Sykes, K., & Ling, W. M. (2004). Exercise training and fall-risk prevention for community-dwelling elders. *American Journal of Recreation Therapy*, 3, 36-42.
- Tabachnick, B.G. & Fidell, L.S. (2007). Using multivariate statistics. Toronto: Pearson.
- Taylor-Piliae, R.E., Newell, K.A., Cherin, R., Lee, M.J., King, A.C., & Haskell, W.L. (2010). Effects of Tai Chi and western exercise on physical and cognitive functioning in healthy community-dwelling older adults. *Journal of Aging and Physical Activity*, 18, 261-279.
- Thiebaud, R.S., Funk, M.D., & Abe, T. (2014). Home-based resistance training for older adults: a systematic review. *Geriatrics and Gerontology International*, 14, 750-757.

- Tinetti, M.E., & Kumar, C. (2010). The patient who falls: "It's always a trade-off." *The Journal of the American Medical Association*, 303, 258-266.
- Tinetti, M.E., & Williams, C.S. (1998). The effect of falls and fall injuries on functioning in community-dwelling older persons. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 53, M112-M119.
- Ullmann, G., Williams, H.G., Hussey, J., Durstine, J.L., & McClenaghan, B.A. (2010). Effects of Feldenkrais exercises on balance, mobility, balance confidence, and gait performance in community-dwelling adults age 65 and older. *The Journal of Alternative and Complementary Medicine*, 16, 97-105.
- Vellas, B.J., Rubenstein, L.Z., Ousset, P.J., Faisant, C., Kostek, V., Nourhashemi, F., & Albarede, J.L. (1997). One-leg standing balance and functional status in a population of 512 community-living elderly persons. *Aging Clinical and Experimental Research*, 9, 95-98.
- Weerdesteyn, V., Rijken, H., Geurts, A.C., Smits-Engelsman, B.C., Mulder, T., & Duysens, J. (2006). A five-week exercise program can reduce falls and improve obstacle avoidance in the elderly. *Gerontology*, 52, 131-141.
- Winter, D. A. (1995). Human balance and posture control during standing and walking. *Gait and Posture*, 3, 193-214.
- Wolfson, L., Whipple, R., Derby, C., Judge, J., King, M., Amerman, P., & Smyers, D. (1996). Balance and strength training in older adults: intervention gains and Tai Chi maintenance. *Journal of the American Geriatrics Society*, 44, 498-506.
- Wong, W.L., Masters, R., Maxwell, J.P., & Abernethy, B. (2008). Reinvestment and falls in community-dwelling older adults. *Neurorehabilitation and Neural Repair*, 22, 410-414.
- Zettel, J.L., Scovil, C.Y., McIlroy, W.E., & Maki, B.E. (2007). Gaze behavior governing balance recovery in an unfamiliar and complex environment. *Neuroscience Letters*, 422, 207-212.

APPENDIX A – ETHICAL CLEARANCE



Brock University
 Research Ethics Office
 Tel: 905-688-5550 ext. 3035
 Email: reb@brocku.ca

Bioscience Research Ethics Board

Certificate of Ethics Clearance for Human Participant Research

DATE: 5/24/2012
 PRINCIPAL INVESTIGATOR: GAMMAGE, Kimberley - Kinesiology
 FILE: 11-267 - GAMMAGE
 TYPE: Faculty Research

 TITLE: Social-Cognitive Mediators of a Balance Training Program in Older Adults

ETHICS CLEARANCE GRANTED

Type of Clearance: NEW Expiry Date: 5/31/2013

The Brock University Bioscience Research Ethics Board has reviewed the above named research proposal and considers the procedures, as described by the applicant, to conform to the University's ethical standards and the Tri-Council Policy Statement. Clearance granted from 5/24/2012 to 5/31/2013.

The Tri-Council Policy Statement requires that ongoing research be monitored by, at a minimum, an annual report. Should your project extend beyond the expiry date, you are required to submit a Renewal form before 5/31/2013. Continued clearance is contingent on timely submission of reports.

To comply with the Tri-Council Policy Statement, you must also submit a final report upon completion of your project. All report forms can be found on the Research Ethics web page at <http://www.brocku.ca/research/policies-and-forms/research-forms>.

In addition, throughout your research, you must report promptly to the REB:

- a) Changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
- b) All adverse and/or unanticipated experiences or events that may have real or potential unfavourable implications for participants;
- c) New information that may adversely affect the safety of the participants or the conduct of the study;
- d) Any changes in your source of funding or new funding to a previously unfunded project.

We wish you success with your research.

Approved:

 Chair
 Bioscience Research Ethics Board

Note: Brock University is accountable for the research carried out in its own jurisdiction or under its auspices and may refuse certain research even though the REB has found it ethically acceptable.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and clearance of those facilities or institutions are obtained and filed with the REB prior to the initiation of research at that site.

APPENDIX B – INFORMED CONSENT

Title of Study: Social-Cognitive Mediators of a Balance Training Program in Older Adults

Principal Investigator: Kimberley L. Gammage, Associate Professor,
Department of Kinesiology, Brock University
905-688-5550 ext. 3772; kgammage@brocku.ca

Co-Investigators: Allan L. Adkin, Associate Professor,
Department of Kinesiology, Brock University
905-688-5550 ext. 4990; allan.adkin@brocku.ca

Lamarche, Ph.D. Candidate, Graduate Department of
Exercise Sciences, University of Toronto
905-688-5550 x4147, larkin.lamarche@utoronto.ca

INVITATION

You are invited to participate in a study that involves research. The purpose of this study is to investigate factors that may influence the effectiveness of a 12-week balance training program in men and women 55 years of age and older.

WHAT'S INVOLVED

As a participant, you will be asked to participate in an initial testing session, in which you will be asked to fill out a series of questionnaires, complete a series of balance tests, and a series of fitness tests. Participation in this session will take approximately 1½ to 1¾ hours of your time. Then, you will be randomly assigned to either the exercise group or a control group. Those in the control group are asked to lead their normal lives, with no changes to their lifestyles. Those in the exercise group will be asked to participate in a 12-week supervised exercise program. You will be asked to attend the exercise sessions 3 times per week at Brock University. Each session will last approximately 60-75 minutes. The exercise program will consist of a brief warm-up, 20 minutes of cardiovascular activity of your choice, strength training, balance training, and flexibility training, followed by a cool-down. At the end of 6 weeks, and again at the end of 12 weeks, all participants will be asked to complete the same questionnaires, balance, and fitness tests as the start of the study. You will also be asked to complete the same testing session 1 year later.

POTENTIAL BENEFITS AND RISKS

Possible benefits of participation include the benefits associated with physical activity. You will also receive information about your own fitness levels. There also may be risks associated with participation. For example, there is some risk of injury associated with any physical activity. There is also a risk of injury due to falling, especially during the balance exercises. All exercise and testing sessions will be supervised by qualified research assistants. The exercise program is designed for all fitness levels, and will progress gradually, at each individual's own pace. In addition, the nature of some of the questionnaires may lead to some psychological discomfort. However, there are no known instances of any problems resulting from anyone completing these questionnaires. If you

do experience any concerns, you may contact Dr. Gammage at the above number or email.

CONFIDENTIALITY

All information you provide is considered confidential; your name will not be included or, in any other way, associated with the data collected in the study. Please note that all exercise sessions are done in a group environment; therefore, your participation in the study cannot be anonymous. You will be provided with an exercise log book with your individual program; we will include only your identification number on the outside of the log book. Logbooks will be kept in the office of the lab and are accessed by the research assistants. In addition, during the balance testing, we will videotape you while on the balance obstacle course only. However, because our interest is in the average responses of the entire group of participants, you will not be identified individually in any way in written reports of this research. Given the format of the group exercise sessions, we ask you to respect your fellow participants by keeping all information that identifies or could potentially identify a participant and/or his/her comments confidential. Data collected during this study will be stored in a locked filing cabinet in a locked storage room on campus. Data will be kept for 1 year following publication of results of the study, after which time all questionnaires will be shredded and videotapes destroyed. Access to this data will be restricted to the investigators listed above, and their student research assistants.

VOLUNTARY PARTICIPATION

Participation in this study is voluntary. If you wish, you may decline to answer any questions or participate in any component of the study. Further, you may decide to withdraw from this study at any time and may do so without any penalty or loss of benefits to which you are entitled.

PUBLICATION OF RESULTS

Results of this study may be published in professional journals and presented at conferences. Feedback about Phase 1 of this study will be available following completion of this phase for all participants. At this time, you will receive feedback about the results of your individual fitness assessments. You may receive a summary of the results of the study via email or regular mail, as requested, by completing the request for feedback form. Feedback about your one-year follow-up fitness tests and about the summary of these results will again be provided (via email or regular mail) upon completion of the entire study. At this time, you may contact us with any questions you may have about the interpretation of your results.

CONTACT INFORMATION AND ETHICS CLEARANCE

If you have any questions about this study or require further information, please contact the Principal Investigator using the contact information provided above. This study has been reviewed and received ethics clearance through the Research Ethics Board at Brock University (File #11-267). If you have any comments or concerns about your rights as a research participant, please contact the Research Ethics Office at (905) 688-5550 Ext. 3035, reb@brocku.ca.

Thank you for your assistance in this project. Please keep a copy of this form for your records.

CONSENT FORM

I agree to participate in this study described above. I have made this decision based on the information I have read in the Information-Consent Letter. I have had the opportunity to receive any additional details I wanted about the study and understand that I may ask questions in the future. I understand that I may withdraw this consent at any time.

Name: _____

Signature: _____ Date: _____

APPENDIX C – DEMOGRAPHIC QUESTIONNAIRE

Age: _____

Gender (please circle): **Male** **Female**

Height: _____

Weight: _____

How many times have you fallen in the past year? _____

Please list the approximate date of the fall, the medical treatment required, and the reason you fell in each case (e.g., uneven surface, going down stairs, etc.).

Have you ever been diagnosed as having any of the following conditions? Please check all that apply.

	Yes	If yes, approximate year of onset?
Heart attack	<input type="checkbox"/>	_____
Angina (chest pain)	<input type="checkbox"/>	_____
Transient ischemic attack	<input type="checkbox"/>	_____
Stroke	<input type="checkbox"/>	_____
Respiratory problems	<input type="checkbox"/>	_____
Diabetes	<input type="checkbox"/>	_____
Cancer	<input type="checkbox"/>	_____
Parkinson's disease	<input type="checkbox"/>	_____
Multiple sclerosis	<input type="checkbox"/>	_____
Other neurological disorders	<input type="checkbox"/>	_____
Rheumatoid Arthritis	<input type="checkbox"/>	_____
Other arthritis	<input type="checkbox"/>	_____
Fracture (< 8 weeks)	<input type="checkbox"/>	_____
Osteoporosis	<input type="checkbox"/>	_____
Joint Replacement	<input type="checkbox"/>	_____
Any other problem (e.g., sensory) that interfere with your balance, walking, or ability to do PA?	<input type="checkbox"/>	_____

Do you wear corrective lenses? Yes No

Do you use an assistive device for walking? Yes No

Do you currently smoke? Yes No

Please list the medications you are currently taking and why.

APPENDIX D - THE ACTIVITIES-SPECIFIC BALANCE CONFIDENCE SCALE

0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
I do not feel at all confident				I feel moderately confident				I feel completely confident		

Please use the scale above to rate the amount of confidence you have in avoiding a fall when you have to:

1. Walk around house

2. Walk up/down stairs

3. Pick up object from floor

4. Reach forward

5. Reach forward on tiptoes

6. Stand on chair to reach object

7. Sweep the floor

8. Walk outside to nearby car

9. Get in/out of car

10. Walk across parking lot

11. Walk up/down ramp

12. Walk in crowded mall

13. Walk in crowd and bumped in to

14. Ride escalator holding rail

15. Ride escalator not holding rail

16. Walk on icy sidewalk

APPENDIX E – TRAIT VERSION OF THE MOVEMENT SPECIFIC
REINVESTMENT SCALE

Directions: Below are a number of statements about your movements. The possible answers go from 'strongly agree' to 'strongly disagree'. There are no right or wrong answers so circle the answer that best describes how you feel for each question.

1. I rarely forget the times when my movements have failed me, however slight the failure.

strongly	moderately	weakly	weakly	moderately	strongly
disagree	disagree	disagree	agree	agree	agree

2. I'm always trying to figure out why my actions failed.

strongly	moderately	weakly	weakly	moderately	strongly
disagree	disagree	disagree	agree	agree	agree

3. I reflect about my movement a lot.

strongly	moderately	weakly	weakly	moderately	strongly
disagree	disagree	disagree	agree	agree	agree

4. I am always trying to think about my movements when I carry them out.

strongly	moderately	weakly	weakly	moderately	strongly
disagree	disagree	disagree	agree	agree	agree

5. I'm self-conscious about the way I look when I am moving.

strongly	moderately	weakly	weakly	moderately	strongly
disagree	disagree	disagree	agree	agree	agree

6. I sometimes have the feeling that I'm watching myself alone.

strongly	moderately	weakly	weakly	moderately	strongly
disagree	disagree	disagree	agree	agree	agree

7. I'm aware of the way my mind and body works when I am carrying out a movement.

strongly	moderately	weakly	weakly	moderately	strongly
disagree	disagree	disagree	agree	agree	agree

8. I'm concerned about my style of moving.

strongly	moderately	weakly	weakly	moderately	strongly
disagree	disagree	disagree	agree	agree	agree

9. If I see my reflection in a shop window, I will examine my movements.

strongly	moderately	weakly	weakly	moderately	strongly
disagree	disagree	disagree	agree	agree	agree

10. I am concerned about what people think about me when I am moving.

strongly	moderately	weakly	weakly	moderately	strongly
disagree	disagree	disagree	agree	agree	agree

APPENDIX F – THE PHYSICAL ACTIVITY READINESS QUESTIONNAIRE

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
<input type="checkbox"/>	<input type="checkbox"/>	1. Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?
<input type="checkbox"/>	<input type="checkbox"/>	2. Do you feel pain in your chest when you do physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	3. In the past month, have you had chest pain when you were not doing physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	4. Do you lose your balance because of dizziness or do you ever lose consciousness?
<input type="checkbox"/>	<input type="checkbox"/>	5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
<input type="checkbox"/>	<input type="checkbox"/>	7. Do you know of <u>any other reason</u> why you should not do physical activity?

If
you
answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- If you are not feeling well because of a temporary illness such as a cold or a fever — wait until you feel better; or
- If you are or may be pregnant — talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME _____

SIGNATURE _____

DATE _____

SIGNATURE OF PATIENT
OR GUARDIAN (for participants under the age of majority) _____

WITNESS _____

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.



© Canadian Society for Exercise Physiology

Supported by:



Health
Canada

Santé
Canada

continued on other side...

APPENDIX G – BASICS EXERCISE LOG SHEET

Cardiovascular Endurance Training (Goal: 20-30 minutes)

Date	Treadmill			Recumbent Bike		Arm Cycle		Arc Trainer			Rowing Machine	
	Speed	Time	Incline	Level	Time	RPM	Time	Level	Incline	Time	Distance	Time

Muscle Strengthening

Muscle		Exercise	Weight	Goal Reps	Sets	Actual # repetitions performed					
#6	Upper Back	Mid row - machine		15	1						
#1	Chest	Vertical chest press - machine		15	1						
#5	Quads	Seated leg press - machine		15	1						
#5	Calves	Seated calf raises – leg press machine		15	1						
#13	Triceps	Triceps pressdown - lat pulldown machine		15	1						
	Biceps	Biceps curl (dumbbells)		15	1						
	Shoulders	Lateral raises (dumbbells)		15	1						
	Legs	Squat with ball against wall		15	1						

Balance/Core Strengthening

Exercise	Equipment/Position	Weight	Goal Reps or Time	Sets	Actual # repetitions performed					
Abs	Sit & lean OR crunches									
Obliques	Sit & twist OR cross-over crunch									
Low Back	Opposite arm-leg raise	---								
Balance	Balance Course	---		2-3						

Flexibility (10-20 seconds each)

Muscle	Completed (✓)					Muscle	Completed (✓)					Muscle	Completed (✓)				
Biceps						Chest						Quadriceps					
Triceps						Hamstrings						Calves					
Shoulders						Gluts						Hip Flexors					
Upper Back						Low Back											